HERBERT M. CARTER

# THESIS

INVESTIGATON OF WATER

SUPPLY SYSTEM

SOUTH HAVEN MICH.

H. M. CARTER E. W. STECK

1911

THESIS

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SOUTH HAVEN
MICH.

This thesis was contributed by

Mr. H. M. Carter

under the date indicated by the department stamp, to replace the original which was destroyed in the fire of March 5, 1916.

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# AN

# INVESTIGATION OF THE WATER SUPPLY SYSTEM

# OF

# SOUTH HAVEN - MICHIGAN.

by

H.M.Carter. E.W.Steck.

1 9 1 1

THESIS

INTRODUCTION.

This Thesis is a discussion of the results shown by analyses of several water samples collected from the water supply of South Haven, Michigan at various times during the month of April 1911, and of data collected concerning the management and operation of the water system of that city. Since it was previously known that an abnormally high case and death rate of Typhoid Fever existed, the investigation was undertaken with the object of determining whether sufficient evidence could be collected to ascribe this to the water supply and if so to discuss the posibility of improving the same. Other data was also collected to determine the condition of the plant and its adequacy for the requirements.

The writers here wish to thank Mr. Mc Ewing, the Superintendent of Public Works and Mr Ocoblock the Engineer at the plant for their kindness and assistance in collecting the data. Also Dr. Holm of the State Board of Health for the analyses of the water samples.

Nearly all the facts given in the following discussion were obtained from the various authorities on Water supply Engineering and are here made reference to as a whole rather than separately in the discussion.

Public Water Supplies. Turneaure and Russel.

Water Supply Engineering. Follwell.

Clean Water and How to Get It. Hazen.

Sewerage. Folwell.

Sewage Disposal. Kinnicut Winslow Pratt.

| | |
|---|---|
| Water Examination | Mason. |
| Sewage Disposal | Rideal. |

Engineering News.

Transactions of American Society of Civil Engineers.

The following was followed in considering the different phases of the subject.

| | |
|---|---|
| Source | Exhaustibility, |
| | Purity. Nature and source of impurities. |
| Plant | Pumping station |
| | Reservoir |
| | Pipe line system |
| Service | Purity of water furnished |
| | Quantity |
| | Fire protection |
| | Waste and leakage |
| Finances | First cost |
| | Method of payment of first cost |
| | Sinking fund |
| | Rates |
| Recommendations for improvements | Source |
| | Pumping |
| | Purification |
| | Measurement |
| | Fire protection. |

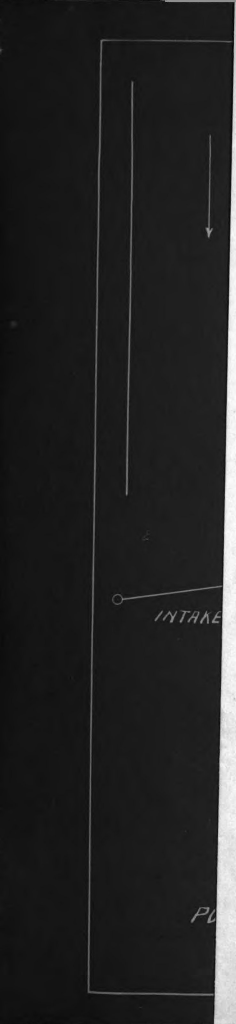
SOURCE OF WATER SUPPLY.

The water supply of South Haven is obtained from Lake Michigan through a twenty inch cast iron intake pipe extending into the lake about 2600 feet. The crib at the end of the intake and the well at the pumping station are as shown in plates 7 and 8. This pipe line runs parallel to the government piers at the mouth of the Black River and about 125 feet south of the south pier. The bearing of the intake and piers is nearly S $79^0$ W. The intake ends in about thirty feet of water and is a little distance beyond the sand bar.

EXHAUSTIBILITY

As far as exhaustibility is concerned there is an unlimited supply of good, clear water of good taste, without odor and free from objectionable chemicals. There are however two serious drawbacks to this source of supply. One is the difficulty of keeping the intake free from sand. The other is of a more serious nature and consists of the contamination of the water by sewage and the danger to the public health from drinking the water from this source. The former is only a problem to be met in the operation of the plant while the latter is of more serious consequence. This is the problem that will now be dealt with.

The following plate shows the relative positions of the river mouth, piers, and intake crib. It also shows the direction of the natural lake currents and the probable influence of the piers and the current from the river upon them.


INTAKE

PURITY OF SOURCE

Before taking up the analyses of the water it was thought advisable to make a comparison of South Haven with several other of the state in regard to the prevalence of Typhoid Fever and of deaths due to that cause. The information necessary for making this comparison was obtained from the reports of the State Board of Health. The writers are indebted to the compiling office of this department for their assistance in collecting the information.

The comparisons were made for the years 1904 to 1909 inclusive. The number of deaths, the number of cases, and the population for each of the above years were obtained for five cities besides South Haven. The cities selected were, Holland, Lansing, Grand Haven, Muskegon, and Ludington. These cities were not selected with the idea of showing how bad South Haven is; but because the conditions seemed such that a fair comparison could be made. Two of these cities, Ludington and Muskegon, obtain their water supply from Lake Michigan while the others have wells to furnish their supply. From these cities the number of cases were also reported thus giving another means of comparison. In several cities only fatal cases were reported thus eliminating them from any comparative study. The number of cases and deaths for each of the several cities were all reduced to a basis of cases and deaths per 10000 population. In this way safe comparisons could be made.

In regard to the case rate per 10000 the results should not be given too much weight as there may be quite a considerable difference in the care with which they are reported from the different cities. In order to obtain a check upon this, the number of cases for the different years for South Haven were obtained both from the city Health Officer and from the records of the State Board of Health. These results compared very favorably so that it is belsived that the results for the other cities are fairly accurately reported. The following table shows the population, cases, and deaths due to Typhoid per 100000 of population for the several cities mentioned.

DEATHS and CASES of TYPHOID FEVER

| CITY | POPULATION | CASES | DEATHS | DEATHS PER 100000 | YEAR |
|---|---|---|---|---|---|
| | 20278 | 27 | 9 | 44.5 | 1904 |
| | 21234 | 13 | 11 | 51.8 | 1905 |
| LANSING | 22172 | 70 | 20 | 90.5 | 1906 |
| | 23119 | 31 | 3 | 13.0 | 1907 |
| | 24067 | 55 | 15 | 62.5 | 1908 |
| | 25015 | 61 | 6 | 24.0 | 1909 |
| | 8966 | 10 | 1 | 11.2 | 1904 |
| | 9260 | 6 | 1 | 10.8 | 1905 |
| HOLLAND | 9554 | 8 | 1 | 10.5 | 1906 |
| | 9848 | 9 | 1 | 9.8 | 1907 |
| | 10142 | 7 | 1 | 10.2 | 1908 |
| | 10438 | 18 | 2 | 19.2 | 1909 |

| CITY | POPULATION | CASES | DEATHS | DEATHS PER 100000 | YEAR |
|---|---|---|---|---|---|
| | 20897 | 25 | 6 | 28.7 | 1904 |
| | 20917 | 30 | 6 | 28.7 | 1905 |
| | 20937 | 18 | 7 | 33.5 | 1906 |
| MUSKEGON | 20956 | 14 | 5 | 14.4 | 1907 |
| | 20976 | 19 | 7 | 33.5 | 1908 |
| | 20995 | 19 | 0 | 00.0 | 1909 |
| | 7259 | 2 | 1 | 13.8 | 1904 |
| | 7282 | 7 | 1 | 13.7 | 1905 |
| | 7306 | 4 | 1 | 13.9 | 1906 |
| LUDINGTON | 7329 | 1 | 1 | 13.6 | 1907 |
| | 7352 | 4 | 4 | 54.5 | 1908 |
| | 7376 | 26 | 7 | 94.5 | 1909 |
| | 5239 | 2 | 0 | 0.0 | 1904 |
| | 5363 | 6 | 1 | 19.1 | 1905 |
| | 5487 | 6 | 3 | 54.5 | 1906 |
| GRAND HAVEN | 5611 | 1 | 1 | 17.9 | 1907 |
| | 5735 | 4 | 0 | 0.0 | 1908 |
| | 5859 | 4 | 1 | 17.1 | 1909 |

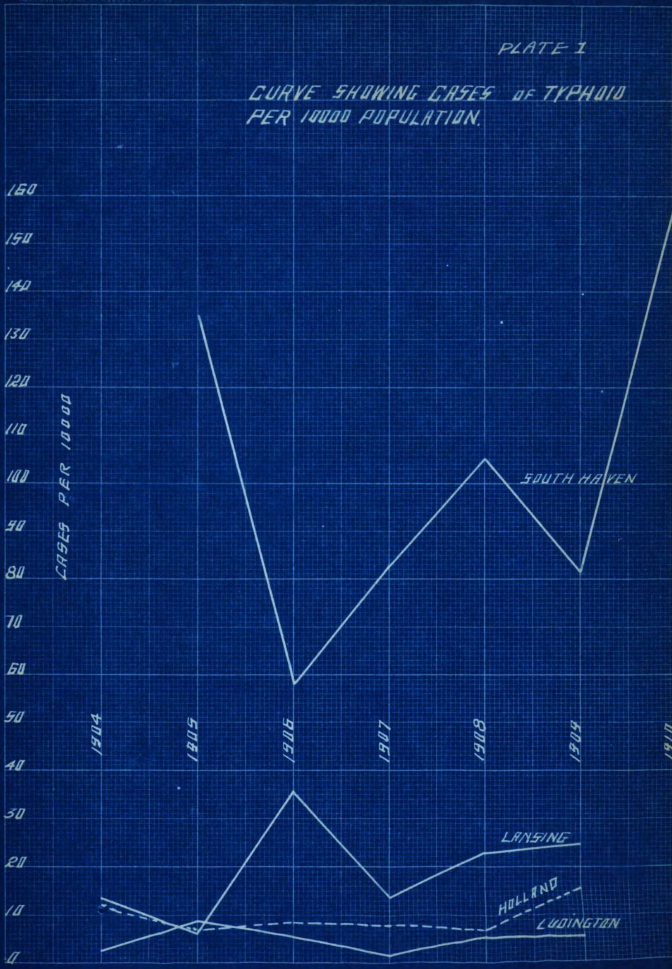


PLATE 1
CURVE SHOWING CASES OF TYPHOID PER 10000 POPULATION.
CASES PER 10000
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1904
1905
1906
1907
1908
1909
1910
SOUTH HAVEN
LANSING
HOLLAND
LUDINGTON

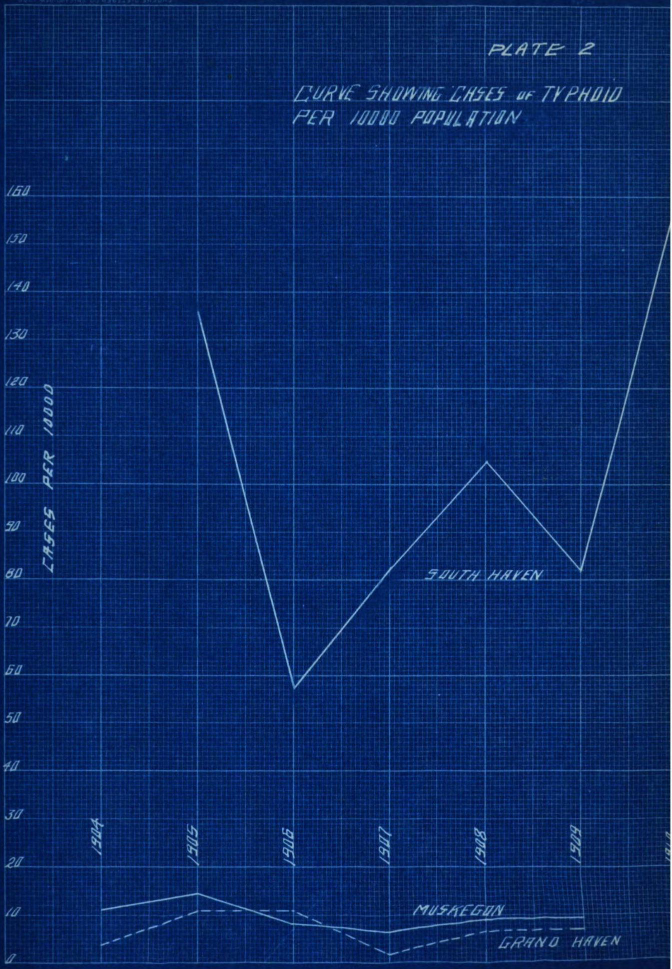


PLATE 2
CURVE SHOWING CASES OF TYPHOID
PER 10000 POPULATION
CASES PER 10000
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1904
1905
1906
1907
1908
1909
SOUTH HAVEN
MUSKEGON
GRAND HAVEN

| CITY | POPULATION | CASES | DEATHS | DEATHS PER 100000 | YEAR |
|---|---|---|---|---|---|
| | 3767 | 41 | 6 | 13.9 | 1904 |
| | 3709 | 80 | 1 | 26.2 | 1905 |
| | 3647 | 21 | 2 | 50.0 | 1906 |
| SOUTH HAVEN | 3586 | 39 | 2 | 50.0 | 1907 |
| | 3526 | 34 | 3 | 75.0 | 1908 |
| | 3466 | 32 | 1 | 24.2 | 1909 |
| | 3700 | 66 | 3 | 72.0 | 1910 |
| | 11098 | 204.0 | 40 | 361.0 | 1904 |
| | 11485 | 21 | 21 | 183.0 | 1905 |
| | 11873 | 14 | 11 | 92.7 | 1906 |
| ESCANABA | 12260 | 52 | 28 | 228.0 | 1907 |
| | 12647 | 87 | 17 | 134.5 | 1908 |
| | 13035 | 44 | 29 | 220.0 | 1909 |
| | 13423 | 8 | 8 | 59.6 | 1910 |

In the following table the cases of typhoid have been reduced to a basis of cases per 10000 population. From these same results curves have been plotted in which the horizontal spaces or abscissae represent the different years and the vertical spaces or ordinates represent the number of cases per 10000 population.

In order to avoid confusion with so many curves on one sheet , the curve for South Haven was redrawn on a second sheet and two of the cities plotted on this sheet, the same scale being used on each sheet.

Case rate of typhoid per 10000 population for the following cities in Michigan.

| YEAR | LANSING | HOLLAND | MUSKEGON | LUDINGTON | GR.HAVEN | SO.HAVEN |
|---|---|---|---|---|---|---|
| 1904 | 15.35 | 11.15 | 11.05 | 2.64 | 3.85 | ---- |
| 1905 | 6.12 | 6.47 | 14.58 | 8.59 | 11.18 | 136.2 |
| 1906 | 35.75 | 8.37 | 8.1 | 5.47 | 10.95 | 57.5 |
| 1907 | 15.45 | 8.11 | 6.7 | 1.57 | 1.78 | 82.1 |
| 1908 | 22.9 | 6.8 | 9.1 | 5.48 | 6.99 | 105.0 |
| 1909 | 24.4 | 15.3 | 9.1 | 5.4 | 6.84 | 81.6 |
| 1910 | -- | -- | -- | -- | -- | 158.4 |

---

The number of deaths due to typhoid fever has been in the same manner reduced to deaths per 10000 population and the results are given in the following table. These results have been plotted, as shown in plates 3 and 4, in the same manner as the case rates .

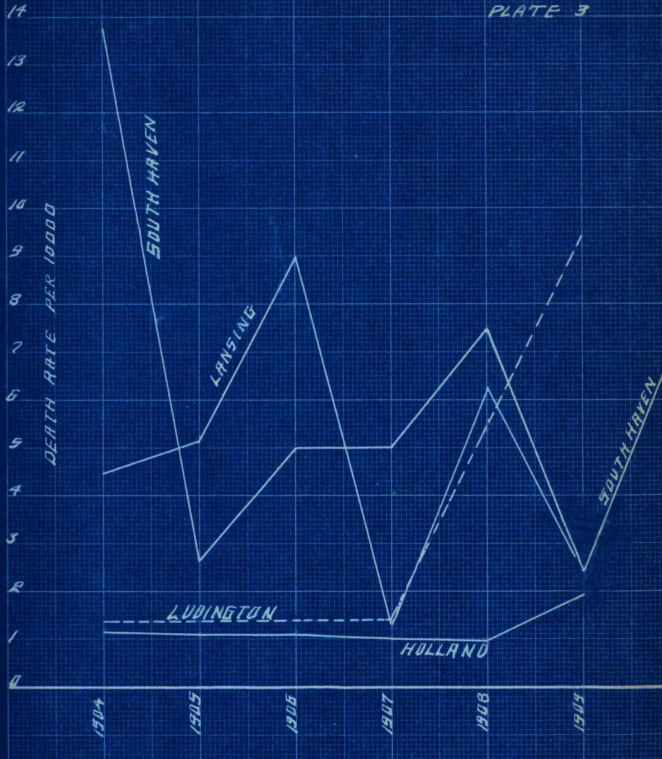
In order to make a comparison of South Haven with the average of the entire state, the curves on Plate 5 were drawn.

The dotted curve showing the average number of deaths per 10000 population for the entire state and the heavy full line showing the same for South Haven. Since the ordinates of these curves are drawn to the same scale as the preceding curves, a comparison can be made with all the other cities and the average for the entire state.

Deaths per 10000 population due to typhoid fever in the following cities of Michigan.

| YEAR | LANSING | HOLLAND | MUSKEGON | LUDINGTON | GR. HAVEN | SO. HAVEN |
|---|---|---|---|---|---|---|
| 1904 | 4.45 | 1.12 | 2.67 | 1.38 | 0.0 | 13.9 |
| 1905 | 5.18 | 1.08 | 2.86 | 1.37 | 1.91 | 2.62 |
| 1906 | 9.05 | 1.05 | 3.35 | 1.37 | 5.45 | 5.00 |
| 1907 | 1.30 | 1.02 | 1.04 | 1.36 | 1.79 | 5.00 |
| 1908 | 6.25 | 0.98 | 3.35 | 5.45 | 0.00 | 7.5 |
| 1909 | 2.4 | 1.92 | 0.00 | 9.40 | 1.71 | 2.42 |
| 1910 | — | — | — | — | — | 7.20 |

PLATE 3




CURVES SHOWING DEATHS
PER 10000 DUE TO TYPHOID

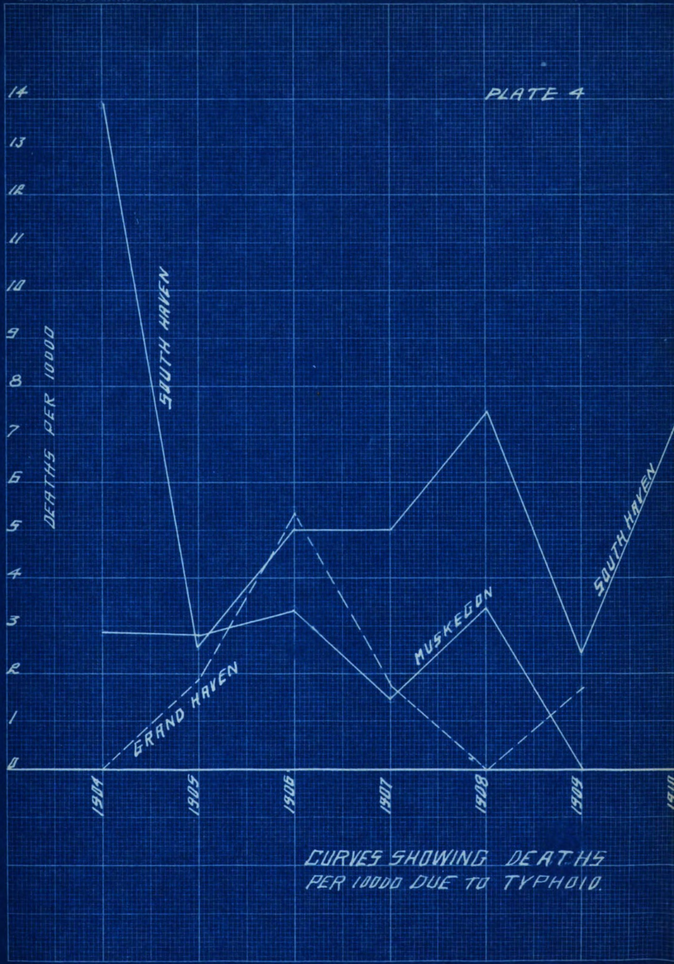


PLATE 4
DEATHS PER 10000
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
SOUTH HAVEN
SOUTH HAVEN
MUSKEGON
GRAND HAVEN
1904
1905
1906
1907
1908
1909
CURVES SHOWING DEATHS
PER 10000 DUE TO TYPHOID.

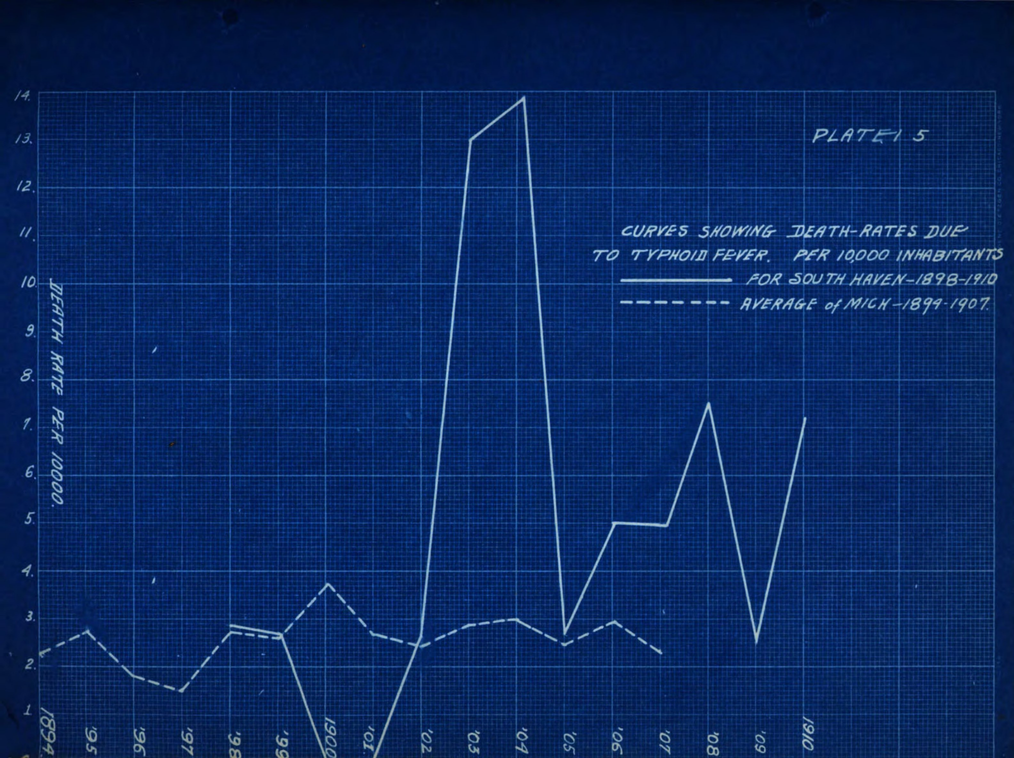


PLATE 5
CURVES SHOWING DEATH-RATES DUE TO TYPHOID FEVER. PER 10,000 INHABITANTS
FOR SOUTH HAVEN-1898-1910
AVERAGE of MICH-1899-1907.
DEATH RATE PER 10000.
14. 13. 12. 11. 10. 9. 8. 7. 6. 5. 4. 3. 2. 1
1894 '95 '96 '97 '98 '99 1900 '01 '02 '03 '04 '05 '06 '07 '08 '09 1910

While the following table is not of particular value in connection with the question of the prevalence of typhoid in the various cities it gives a comparison of the conditions during the year 1909 with the average of the five years previous.

In two of the cities, Ludington and Holland, conditions were worse than the average, while in the other four they were more favorable.

Comparison of '09 with the average of '04 to '08.

| CITY | POPULATION | CASES | DEATHS | DEATHS PER 100000. |
|---|---|---|---|---|
| Lansing '09 | 25015 | 61 | 6 | 24 |
| Av. '04-'08 | 22175 | 48 | 12 | 54.1 |
| Holland '09 | 10436 | 16 | 2 | 19.2 |
| Av. '04-'08 | 9554 | 8 | 1 | 10.5 |
| Muskegon '09 | 20995 | 19 | 0 | 0.0 |
| Av. '04-'08 | 20937 | 21 | 6 | 28.7 |
| Ludington '09 | 7376 | 26 | 7 | 94.9 |
| Av. '04-'08 | 7306 | 4 | 2 | 27.4 |
| Gr. Haven '09 | 5859 | 4 | 1 | 17.1 |
| Av. '04-08 | 5487 | 4 | 1 | 18.2 |
| South Haven '09 | 3466 | 59 | 1 | 24.2 |
| Av. '04-'08 | 3646 | 37 | 3.2 | 43.0 |

Conclusions drawn from above curves and tables.

The most striking difference is in the curves showing the number of cases per 10000. From these it is seen that the case rate is several times greater in South Haven than in any of the other citi The next highest is Lansing. This is such a wide difference that one is tempted to question the accuracy of the reports. But even with a large factor allowed for possible errors, the case rate in South Haven is abnormally high. This is further established by a comparison of the death rate curves. The difference in these is not so widely marked but on the whole the curves for South Haven are much higher than any of the others, that of Lansing being next in order.

From these comparisons it is quite evident that both the case rate and the death rate are higher than any of the other cities, in fact it was found that there are only two cities in Michigan having a higher death rate from typhoid fever than South Haven. These two cities are Escanaba and Wyandotte.

The question will at once come up as to what is the cause of this condition. Typhoid fever is an intestinal disease and and to be contracted the typhoid bacilli must as a general rule be taken into the body with the food or drink. The bacilli are expelled from the body in the dejecta and urine, and the great majority of cases come from the careless disposal of these excretio There is the further difficulty that these germs will live and retain there vitality for a considerable time in water. This renders any river, lake , or well into which sewage can obtain access, exceedingly dangerous as a source for drinking water.

Thus there are sources of danger from typhoid from rivers or lakes into which sewage is emptied and shallow wells or springs into which the contents of open privies can percolate. Besides these the typhoid bacilli may be carried by flies from open privies and deposited on food. This renders the open privy and shallow well very dangerous. Of course some cases come from contact with typhoid patients but these are not very numerous and typhoid may be regarded as coming almost entirely from or with food and water.

There is a possibility that a considerable amount of typhoid comes from the wells and open privies of South Haven, but this would not account for all of it and the water supply would come under suspicion. The analyses and comparisons of this will be given later.

Another striking fact is the difference between the case and the death rate in South Haven as compared to the other cities, as shown by the following table:

Average of cases and deaths per 10000 for 1904 to 1909.

| CITIES | CASES | DEATHS | PERCENTAGE OF FATAL CASES |
|---|---|---|---|
| Lansing | 22.97 | 4.6 | 20.5 |
| Holland | 9.38 | 1.19 | 12.7 |
| Muskegon | 9.73 | 2.31 | 23.8 |
| Grand Haven | 6.93 | 1.18 | [illegible]6.2 |
| South Haven | 103.4 | 6.07 | 5.9 |

This shows that while the case rate and also the death rate are higher for South Haven, the percentage of cases proving fatal is less. It is hard to give an explanation of the difference, as it may be that the city is situated in a higher and more healthful location, that the city not being a manufacturing town has not the foreign element in such numbers or that the people are becoming immune to the effects of the disease to a slight extent.

## Analyses of water.

Samples of the water were taken from the lake and the mains of the city at different points and times, and were sent to the laboratory of the State Board of Health at Lansing, Mich.

Before taking up the discussions of the results of the analyses , it is thought best to give an outline of what is taken into consideration in the analysis of water, chemically and bacteriologicaly and what is indicated by the presence of the different substances present.

The first four items, color, turbidity, odor and sediment are readily understood and have no direct bearing on the purity of water. However to be suitable for drinking purposes water should be colorless, without disagreeable odor or taste, and free sediment. These facts alone would not condemn a water supply but taken into consideration with others might have some weight in rejecting or accepting a water for this purpose.

The next substances considered are nitrogen as free ammonia and nitrogen as albuminoid ammonia. These coumpounds are of important significance in a chemical analysis . They result from the decomposition of organic matter and while the free ammonia may indicate the decay of vegetable matter , the albuminoid more often results from the decomposition of animal matter or refuse.

Since these substances invariably accompany sewage pollution their presence is of sanitary significance . Generally a high ratio of albuminoid to free ammonia with small quanities of nitrates and a chlorine indicates vegetable pollution . Larger amounts of free ammonia with an excess of chlorides show the presence of animal matter. Therefore the presence of these two is taken as an index of sewage contamination.

The Chicago Health authorities say in regard to the water of Lake Michigan: "From time to time analyses are made of undefiled water from mid-lake. A certain normal amount of free and albuminoid ammonia is found to be present, usualy 0.01 free and 0.07 albuminoid. In case however, that sewage has reached the cribs we find the ammonias are present in much larger quanities. As a rule water showing as much as 0.02 free and 0.09 of albuminoid is to be considered as doubtful and anything above this is dangerous. "Masons Water Examination" P. 74.

The presence of nitrogen as nitrates represents an intermediate stage of decomposition and indicates that the water is at present polluted with organic matter in which germ life is present . This is then an unfavorable indication in water if present in any considerable amount. The presence of nitrites in some deep w ells is not always an indication of impurity but a considerable quantity together with an excess of free ammonia is usualy due to sewage pollution in either surface or ground water.

Nitrogen as nitrates represents the final stage of decomposition in organic matter. In it self it may indicate only past pollution without any present danger in using the water

but if found with free ammonia or nitrites it shows the presence of pollution and decomposing organic matter.

## CHLORINE

Chlorine is one of the substances which is almost invariably present in any water and yet there is hardly any factor in water analyses which should be given closer attention. Chlorine is usualy present in the form of common salt washed from the air, the soil or obtained from sewage contamination. Salt in itself is not a dangerous impurity in the water but as it is largely used in our food the presence of large amounts of Chlorine points to sewage contamination. In some cases, as in central Michigan where there are numerous salt wells it would not be an indication of impurity while in other localities it would be extremely objectionable. Water from Lake Michigan should not be high in Chlorine as in this case it would indicate sewage pollution.

## OXYGEN CONSUMED

Another method of making comparisons of the quanity of organic matter present in a water is by means of the oxygen consumed. In a water rich in organic matter the carbon in the matter readily takes on oxygen and in this way its amount is aproximately determined. This is done by adding permanganate of potash. Surface water or peaty waters show a high oxygen consuming capacity. The amount of oxygen consumed shows therefore the amount of organic matter present but does not indicate wether it is of vegetable or organic origin.

## ALKALINITY AND HARDNESS

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## ALKALINITY AND HARDNESS

These two determinations are not usualy of such impor-
ance

tance as the others as they indicate the presence of chemical compounds which are not usualy important in considering a water for drinking purposes. If however the water is to be used in chemical manufactures may become of importance, or for water for boiler plants.

IGNITED SOLIDS

The ignited solids are of importance in indicating the quantity of organic matter present. If a sample of water be evaporated all chemical and organic matter will be left behind and its amount determined. If then this residue be heated to redness the organic matter will be oxidised and driven off leaving only the mineral elements and the ash. If the ash is white it usualy indicates the presence of mineral solids. If much organic matter is present the ash will turn black and give off the odor of vegetable or animal substances. The difference between the weights of total solids after drying and after burning indicates the quantity of organic matter present.

IRON

Iron is not such an important item and except for laundry use is not objectionable in reasonable quantities.

From this it will ne seen that the important items in a chemical analysis are the free and the albuminoid ammonia, nitrites, nitrates, and chlorine, Oxygen consumed and ignited solids. These all point towards sewage contamination if present in large quantities, and where they are high, and there is known possibility of sewage pollution the water should be regarded as dangerous.

## BACTERIOLOGICAL ANALYSIS

While the results of a chemical analysis are sometimes indefinite and it is difficult to decide whether pollution is from animal or vegetable sources, it might reasonably be supposed that a bacteriological examination would be a direct means of determining the purity of water. This is not the case however as the search in such an examination is not directly for the specific disease germ but for those conditions which indicate sewage pollution.

The number of colonies per cubic centimeter furnishes a good means of comparison of the water supply at different times but is not conclusive evidence of contamination, as many of these bacteria might be of an entirely harmless nature. When incubated at body temperature however many of these harmless varieties do not live and those which might be supposed to live in the human system would developed. The most important test is that for Bacillus Coli. This bacillus is one found in the intestinal tract of man and also the lower animal. A water which then shows the presence of bacillus coli is to be regarded as suspicious and even dangerous, for it is direct evidence of sewage contamination. If these bacilli are present it only requires the accident of disease to bring danger of an epidemic of typhoid or other water borne disease. Because of the diffuclty of separating the Typhoid Bacilli from its closely related associate the Colon Bacillus the latter is taken as an indication of a dangorous water. If a large percentage of one c.c. tests reveal the presence of the latter form it is taken as evidence of a dangerous condition

of the water supply. The presumptive tests for Bacillus Coli as the production of gas are also of value in determining the quality, as total freedom from gas generating organisms is only associated with unpolluted water.

Standards of purity for water supply.

The following two analyses represent what is considered to be the composition of good water by Merriman, and the limit established by the Michigan State Board of Health. The third is an analysis of sewage by Merriman. The analysis is given in parts per million.

| | Merriman (Good water.) | Limit of Drinking (water. Mich. B.H.) | Merriman (Sewage) |
|---|---|---|---|
| Total solids | 50 | 500 | 700 |
| Organic " | 30 | 300 | 200 |
| Inorganic " | 20 | 200 | 500 |
| Chlorine | 3.00 | 12.1 | 40 |
| Free Ammonia | 0.01 | 0.05 | 25 |
| Alb. " | 0.1 | 0.15 | 10 |
| Nitrites | 0.2 | 0.9 | 0.1 |
| Nitrates | 0.0 | trace | 0.005 |
| Oxygen consumed | 0.5 | 2.2 | 40.0 |
| Bacteria per c.c. | 25.0 | no toxicogenic | 1000000 |
| Hardness | -- | 80 | -- |
| Organic carbon | -- | -- | -- |

These tables represent an attempt to formulate a standard of purity for water and while in a general way they may apply to some localities they will not hold in all cases. The variety of local conditions which are met with render it impossible to apply these standards. For instance a water high in Chlorine may be perfectly wholesome in one locality while in another it would be dangerous.

In drawing conclusions from the results of an analysis all the local conditions and possibilities of contamination must be taken into consideration to make a safe decision as to the purity of the water.

The following is an analysis of a sample of water taken from the mains of South Haven, on March 17, 1911. At this time there had been a severe northwest storm for several days and it was thought by the local Health Officer that since the intake is located south of the river mouth, the water would be in the worst possible condition.

Analyses of water from South Haven public supply, March 17, 1911, taken from the tap.

| | |
|---|---|
| Color | None |
| Odor | Musty |
| Turbidity | 5 |
| Sediment | Trace |
| N. as Free Amm. | .040 |
| N. as Alb. Amm. | .0100 |
| N. as Nitrites | .000 |
| N. as Nitrates | .500 |
| Chlorine | 6.000 |
| Oxygen consumed | 5.500 |
| Alkalinity | 155.000 |
| Hardness | 155.000 |
| Ignited Solids | 130.000 |
| Iron | .300 |

BACTERIOLOGICAL

| | |
|---|---|
| Colonies per C.C. room temp. | 120 |
| " " " Inc. " | 18 |
| Presumptive tests for Bacillus Coli | |
| Gas production on Lactose B. | |
| 1 c.c. | None |
| 25 " | 10% |
| Acidity | Marked |
| Turbidity | " |
| Indol production | Present |
| Red colonies on L.L.A. | None |
| Bacillus Coli | Few |
| Potability | Suspicious |

The Bacterial findings in this water, at the time this sample was taken, are not extremely bad, but we cannot regard the water as safe. M.L.Holm.

From the results of this analysis it is seen that the water was quite turbid and of a musty odor. The turbidity was due to the weather conditions. The quanity of free and albuminoid ammonia together with the high Chlorine value indicates the presence of organic matter, and present sewage contamination. The excess of Nitrates is also an indication of sewage pollution as is the oxygen consumed. The colonies of Bacteria at room temperature are higher than is permissable in good water, and the number at the incubated temperature indicates that there are those present which develop under conditions similiar to those in the human system. The presence of Bacillus Coli points conclusively to sewage pollution and renders the water suspicious, if not even dangerous.

From these results it is beleived that the water supply under conditions of that day is not safe for drinking purposes. If such conditions remain for any length of time it would require only the presence of any considerable number of cases of Typhoid to render it very dangorous.

The following analyses give the results from four samples of water taken at South Haven May 16 1911. These samples were taken as nearly simultaneously as possible and at the following places Number 1 taken at the City.Hall. Number 2taken at the pumps. Number 3 taken 1500 feet beyond the present intake,in the lake and nearly at the bottom. Number 4 taken as nearly over the intake as possible to locate it and near the bottom.

The object of taking these four was to determine if possible the effect of pipe system on the water by comparing the sample at the City Hall with the one at the pumps. Then by a comparison of the one at the pumps with the one at the intake to determine if there was a break in the intake pipe.Number 4 was taken to determine whether the quality of the water could be improved to a satisfactory degree by extending the present intake further into the lake. On the day these samples were taken the lake was perfectly quiet and there was practicaly no wind. This was almost the opposite extreme from that under which the first samples were taken.

The four samples of water received April 28th from South Haven ,#2 taken pump at power house ,# 1taken at the City Hall,# 3 taken 1500 feet from mouth of intake,and # 4 taken at the mouth of the intake,have been examined with the following results,-

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Color | None | None | None | None |
| Odor | None | None | None | None |
| Turbidity | None | None | None | None |
| Sediment | None | None | None | None |
| N. as free Amm. | .010 | .010 | .030 | .010 |
| N. as Alb. Amm. | .020 | .060 | .070 | .060 |
| N. as Nitrites | .002 | .001 | .010 | .015 |
| N. as Nitrates | .050 | .050 | .050 | .050 |
| Chlorine | 6.000 | 6.000 | 5.000 | 6.000 |
| Oxygen consumed | 2.600 | 1.800 | 2.800 | 3.300 |
| Alkalinity | 135.000 | 135.000 | 130.000 | 135.000 |
| Hardness | 135.000 | 135.000 | 130.000 | 140.000 |
| Ignited solids | 120.000 | 130.000 | 120.000 | 140.000 |
| Iron | .500 | .400 | .300 | .300 |

BACTERIOLOGICAL

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Colonies per c.c. Room temp. | 65 | 125 | 130 | 65 |
| " " " Inc. B | 8 | 22 | 45 | 5 |

Presumptive tests for B.COLI

Gas production on Lactose B.

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 cc | None | 12% | 5% | 2% |
| 25 cc | 40% | 45% | 45% | 40% |
| Acidity | Marked | Marked | Marked | Marked |
| Turbidity | Marked | Marked | Marked | Marked |
| Indol production | Present | Present | Present | Present |

| | #1 | #2 | #3 | #4 |
|---|---|---|---|---|
| Red colonies on L.L.A. | None | 1 | 4 | 2 |
| B.Colli ------------ | Few | Present | Present | Present |
| Potability ---------- | Suspicious | Unsafe | Unsafe | Unsafe |

All these samples the presence of a certain amount of sewage contamination.

The findings are not very bad in sample #1. Sample #2 shows somewhat more contamination and sample #4 a still higher increase. Sample #3 appears to be the worst of the lot from a bacterial standpoint, showing the highest number of sewage bacteria.

M.L.Holm.

In making a comparison of the samples it is to be noted that all show the presence of sewage contamination by the quantity of albuminoid ammonia, chlorine, and oxygen consumed. The of colonies at room temperature are rather high and at the incubated temperature several were presence The gas production indicates the presence of Bacillus Colli which were found in all samples None of these samples could be considered safe for drinking purposes. There is a marked difference between the first two samples as shown by the higher values for albuminoid ammonia, nitrites, oxygen consumed, iron, and bacteria in sample # 1 This is due to the fact that part of the organic matter was deposited as sediment in the pipes when the velocity decreased due to the branching of the mains. Samples # 3 and 4 show the same things as # 1 and # 2, That is the presence of sewage contamination.

In comparing # 2 and # 4 it is to be noticed that although in the chemical analysis # 4 gives a little higher values there is not much difference between them. From this it is safe to conclude that there is no serious leak or break in the intake at least near the shore. The increase in iron is due to the solvent action on the main in passing through it. The increase in bacteria may be due to the straining action in the pipe, breaking up the colonies, or more likely that the sample # 4 was not taken directly over the intake and the sample was not identical with taken at the pumps.

The most surprising fact to be noticed in comparing # 3 and # 4 is that the sample taken farthest out in the lake is the worst. The can be seen in the free ammonia .05 against .01 over the intake and the albuminoid ammonia .07 against .06. The other items show that while still polluted it is slightly reduced in quantity. The most striking difference is in the number of colonies of bacteria per cc., 130 beyond the intake and 85 at the intake. Both these samples represent dangerous water and further that it is doubtfull whether a safe water could be obtained by going a reasonable distance farther out onto the lake. IT must be remembered however that this is only one test and that in order to decide this conclusively it would be necessary to make a series of tests extending over a considerable period of time.

Another test was made May 15th 1911, consisting of two samples, one taken at the City Hall and the other 4000 feet out in the lake or about the same distance beyond the intake as in the previous set of samples. For several days before this the wind had been blowing from the south west although at the time the samples were taken it was comparatively quiet. At this same time a dredge was working in the harbor and material was being carried out into the lake and dumped about one half mile south west of the intake. Itwas thought that this might have some effect on the quality of the water. The two samples of water received from South Haven May 16th, give the, following results on examination.

| | 4000 ft. out | | City Hall |
|---|---|---|---|
| Color ---------- | None | --- | None |
| Odor ---------- | None | --- | None |
| Turbidity ----- | None | --- | None |
| Sediment ------- | None | --- | None |
| N. as Free Amm. ---- | .010 | --- | .010 |
| N. as Alb. Amm. --- | .060 | --- | .040 |
| N. as Nitrites ----- | .000 | --- | .001 |
| N. as Nitrates ----- | .080 | --- | .060 |
| Chlorine ----------- | 5.000 | -- | 5.000 |
| Oxygen consumed -- | 1.600 | --- | 1.400 |
| Alkalinity ----- | 125.000 | --- | 125.000 |
| Hardness -------- | 125.000 | --- | 125.000 |
| Ignited solids - | 125.000 | --- | 125.000 |
| Iron ---------- | .400 | --- | .300 |

BACTERIOLOGICAL

| | | |
|---|---|---|
| Colonies per cc at room temp. | 75 | 25 |
| " " " " Inc. " | 0 | 1 |
| Presumptive tests for B.Coli | | |
| gas production on Lactose B. | | |
| 1 C.C. | None | None |
| 25 C.C. | NONE | NONE |
| Acidity | None | None |
| Turbidity | None | None |
| Indol production | None | None |

| | 4000 ft. out | City Hall |
|---|---|---|
| Red colonies on L.L.A. | None | None |
| B. Coli | None | None |
| Potability | Safe | Safe |

These are both good waters. M.L.Holm.

These samples show a very fair condition of the water at that time. In the chemical analysis the quantity of albuminoid ammonia as well as the Nitrates are rather high and there is slight evidence of sewage contamination. By comparing the two however it will be seen that the sample taken farther out is not much better than that at the present point of supply. Some of the difference of the two samples is accounted for by the settling action going on in the mains after being pumped. As the analyses stand however, that farther out is the worse, but taking into consideration the settling there would probably not be a very great difference between them.

For the purpose of comparing South Haven water with the other cities used in comparing the typhoid statistics, the following analyses are included. Two of these , Ludington and Muskegon obtain there water from the same source, that is Lake Michigan. In both cases however they extend farther out into the lake. The other three Lansing, Grand Haven, and Holland, obtain there water supply from wells, those at Lansing being quite deep.

## MUSKEGON CITY WATER.

| | |
|---|---|
| Color | None |
| Odor | Faint |
| Turbidity | None |
| Sediment | None |
| N. as Free Amm. | .010 |
| N. as Alb. Amm. | .060 |
| N. as Nitrites | .000 |
| N. as Nitrates | .100 |
| Chlorine | 5.000 |
| Oxygen consumed | 2.600 |
| Alkalinity | 125.000 |
| Hardness | 135.000 |
| Ignited solids | 105.0000 |
| Iron | .200 |
| **BACTERIOLOGICAL** | |
| Colonies per c.c. at room temp. | 34.000 |
| " " " " Inc. " | 4.000 |
| Presumptive tests for B. Coli | |
| Gas production on Lactose B. | |
| 1 c.c. | None |
| 25 c.c. | 20% |
| Acidity | Marked |
| Turbidity | " |
| Indol production | Present |
| Red colonies on L.L.A. | None |
| B. Coli | Few |
| Potability | Suspicious |

This water is regarded as relatively safe. It is not very bad but may vary from time to time owing to closeness to shore.

## LUDINGTON CITY WATER.

Sample taken from faucet. The water source is Lake Michigan and owing to accident to intake the water is being drawn 200 feet from shore.

| | |
|---|---|
| Color | 5 |
| Odor | Faint |
| Turbidity | None |
| Sediment | None |
| N. as Free Amm. | .010 |
| N. as Alb. Amm. | .080 |
| N. as Nitrites | .000 |
| N. as Nitrates | .060 |
| Chlorine | 7.000 |
| Oxygen consumed | 4.100 |
| Alkinity | 124.000 |
| Hardness | 125.000 |
| Ignited solids | 130.000 |
| Iron | .400 |

### BACTERIOLOGICAL

| | |
|---|---|
| Colonies per c.c. room temp. | 140. |
| " " " Inc. temp. | 40. |
| Presumptive tests for B. Coli | |
| Gas production on Lactose B. | |
| 1 c.c. | None |
| 25 " | 30% |
| Acidity | Marked |
| Turbidity | " |

| | |
|---|---|
| Indol Production | Present |
| Red colonies on L.L.A. | None |
| B. Coli | Few |
| Potability | Suspicious |

This water is not very bad.

Ludington city water after being treated with hypochlorite of lime.

| | |
|---|---|
| Color | 5 |
| Odor | Faint, Chlorine |
| Turbidity | None |
| Sediment | None |
| N. as Free Amm. | .030 |
| N. as Alb. AMM. | .080 |
| N. as Nitrites | .000 |
| N. as Nitrates | .080 |
| Chlorine | 10.000 |
| Oxygen consumed | 6.000 |
| Alkalinity | 180.000 |
| Hardness | 1[illegible]5.000 |
| Ignited solids | 115.00 |
| Iron | .700 |

BACTERIOLOGICAL

| | |
|---|---|
| Colonies per c.c. room temp. | 8 |
| " " " Inc. Temp. | 2 |
| Presumptive tests for B. Coli | |
| Gas production on Lactose B. | |
| 1 c.c. | None |

| | |
|---|---|
| 25 c.c. | None |
| Acidity | None |
| Turbidity | None |
| Indol production | None |
| Red colonies on L.L.A. | None |
| B. Coli | None |
| Potability | Safe |

This sample after treatment seems to indicate more contaminatio n than before treatment. Evidently the second sample was more contaminated than the first.

HOLLAND CITY WATER. March 13, 1909.

| | |
|---|---|
| Color | None |
| Odor | None |
| Turbidity | None |
| Sediment | None |
| N. as Free Amm. | .000 |
| N. as Alb. Amm. | .030 |
| N. as Nitrites | .005 |
| N. as Nitrates | .800 |
| Chlorine | 10.000 |
| Oxygen consumed | .600 |
| Alkalinity | 150.000 |
| Hardness | 160.000 |
| Ignited solids | 180.000 |
| Iron | .050 |

BACTERIOLOGICAL

| | |
|---|---|
| Colonies per c.c. Room Temp. | 2 |
| " " " Inc. Temp. | 0 |
| Presumptive tests for B. Coli | |
| Gas production on Lactose B. | |
| 1 c.c. | None |
| 25 " | None |
| Acidity | None |
| Turbidity | None |
| Indol production | None |
| Red colonies on L.L.A. | None |
| B. Coli | None |
| Potability | Safe |

LANSING PURE"ICE" WATER. March 15, 1911.
(Distilled and pure ice from drinking fountain.)

| | |
|---|---|
| Color | None |
| Odor | None |
| Turbidity | None |
| Sediment | None |
| N. as Free Amm. | .150 |
| N. as Alb. Amm. | .010 |
| N. as Nitrites | .999 |
| N. as Nitrates | .900 |
| Chlorine | 4.000 |
| Oxygen consumed | 1.800 |
| Alkalinity | 75.000 |
| Hardness | 75.000 |
| Ignited solids | 70.000 |
| Iron | .100 |

BACTERIOLOGICAL.

| | |
|---|---|
| Colonies per c.c. at room temp. | 29 |
| " " " " inc. " | 6 |
| Presumptive tests for B. COLI | |
| Gas production on Lactose B. | |
| 1 c.c. | None |
| 25 " | None |
| Acidity | None |
| Turbidity | None |
| Indol production | None |
| Red colonies on L.L.A. | None |
| B. Coli | None |
| Potability | Safe |

This analysis shows that absolutely pure water was not used . It would seem that about two thirds was distilled and one third raw water.

LANSING CITY WATER.

Water taken from the Capitol Building on March 15, 1911.

| | |
|---|---|
| Color | None |
| Odor | None |
| Turbidity | None |
| Sediment | None |
| N. as Free Amm. | .060 |
| N. as Alb. Amm. | .030 |
| N. as Nitrites | .000 |
| N. as Nitrates | .000 |
| Chlorine | 13.000 |
| Oxygen consumed | 2.100 |

| | |
|---|---|
| Alkalinity | 295.000 |
| Hardness | 300.000 |
| Ignited solids | 285.000 |
| Iron | .900 |

BACTERIOLOGICAL.

| | |
|---|---|
| Colonies per c.c. at Room Temp. | 19 |
| " " " " Inc. " | 0 |
| Presumptive tests for B. Coli | |
| Gas production on Lactose B. | |
| 1 c.c. | None |
| Two c.c. | None |
| Acidity | None |
| Turbidity | None |
| Indol production | None |
| Red colonies in L. L. A. | None |
| B. Coli | None |
| Potability | Safe |

By comparing the analyses from Muskegon and Ludington to those of South Haven it will be seen that the water is very similar and shows the same sewage pollution. The second sample of Ludington water is of interest because it represents water treated with Hypochlorite of lime. These two were supposed to represent water before treatment and after but it is very evident that at some time must have elapsed between taking the samples, as the second is much worse than the first. This emphasizes the care which must be observed in taking the water samples. The greatest difficulty with most of the samples sent to the state laboratory is along this line and complete history of the water, the sample, the weather conditions and the time between samples should be sent along with them to make the results of the greatest value.

The samples from Lansig and Holland show differences between the lake water and that from the wells. The sample from Holland shows a better combination than that at Lansing no account of the high amonias, chlorine, and oxy gen consumed of the latter. The analyses of Lansing water one the city water the other the Lansing pure ice water are of interest in showing the value of such an analysis. The pure ice water is supposed to be made from distilled water and ice from distilled water. The results of the analyses, while the samples represents excellent water, shows that distilled water was not used entirely and that probably one third of the sample consisted of raw water.

From the results of these samples it is evident that the present water supply of South Haven while safe under certain weather conditions is very uncertain and that under a great number is doubtfull and even dangerous. It is believed that the evidence is suffient for condemning the supply. It is doubtful whether the supply could be improved sufficiently by extending the intake 1,000 feet farther into the lake.

QUANTITY OF WATER PUMPED.

The quantity of water pumped is obtained from the number of strokes and displacement of the pumps. To each pump is attached a Bristol recording meter and daily readings are takenoff the number of strokes. This method of obtaining the quantity of water pumped is not strictly correct as it does not take into consideration the slip of the pumps. However for comparison it is fairly accurate, and will give fairly good results.

For the Gould Triplex which has a piston diameter of 11 inches and a stroke of 10. The displacement of one cylinder would be as follows

Displacement = $\frac{1}{4}$ x 3.1416 $D^2$ x length of stroke.

" equals 1/4 x 3.1416 x 11 x 11 x 10

" 950.384 cubic inches.

Displacement in gallons = 950.384 divided by 231

= 4.114

For one revolution of the pump as recorded by the counter the displacement would be:

4.114 x 3 = 12.34 gallons.

In computing the number of gallons given below, the displacement was used as 12 gallons. This is a very fair assumption and allows somewhat for the slip of the pumps. The allowance being .34 ÷ 12.34 = 2.75 %, which for this type of pump in good condition is probably very near the true amount of slip.

In the other two pumps, which are Hughes Duplex High Pressure pumps ( 14 x 8½ x 12 ) the displacement would be

$\frac{1}{4}$ x 3.1416 x diameter$^2$ x length of stroke.

= $\frac{1}{4}$ x 3.1416 x $8\frac{1}{2}^2$ x 12

= 781.06 cubic inches, or 3.38 gallons.

Since these are duplex double acting pumps, each stroke registered on the recording meter represents four displacements or the displacement for each registered stroke is 13.5 gallons. In estimating the daily quantities of water pumped this amount was assumed as 12 gallons, leaving for slip 1.5 gallons or 11% slip. This amount of slip is not excessive for a duplex pump. Owing to the shortness of the time there was no opportunity of making a test of the actual percent of slip.

From the records of the Water Works Committee the water pumped for the fiscal year March 1, 1910 to Feb. 28, 1911, inclusive is given by the following table:

| 1910 | TOTAL WATER PUMPED In gallons. | DAILY AVERAGE |
|---|---|---|
| March | 9659450 | 311870 |
| April | 8241300 | 274712 |
| May | 8390600 | 284213 |
| June | 9584400 | 319480 |
| July | 15035900 | 485 030 |
| August | 16750450 | 540351 |
| Sept. | 9461900 | 315397 |
| Oct. | 8200180 | 264523 |
| Nov. | 7954320 | 265144 |
| Dec. | 7595610 | 298568 |
| Jan. 1911 | 9055610 | 244056 |
| Feb. " | 6407370 | 252048 |

The total quantity of water pumped for the year is 115,417,980gallons . Daily average for year is 316213 gallons.

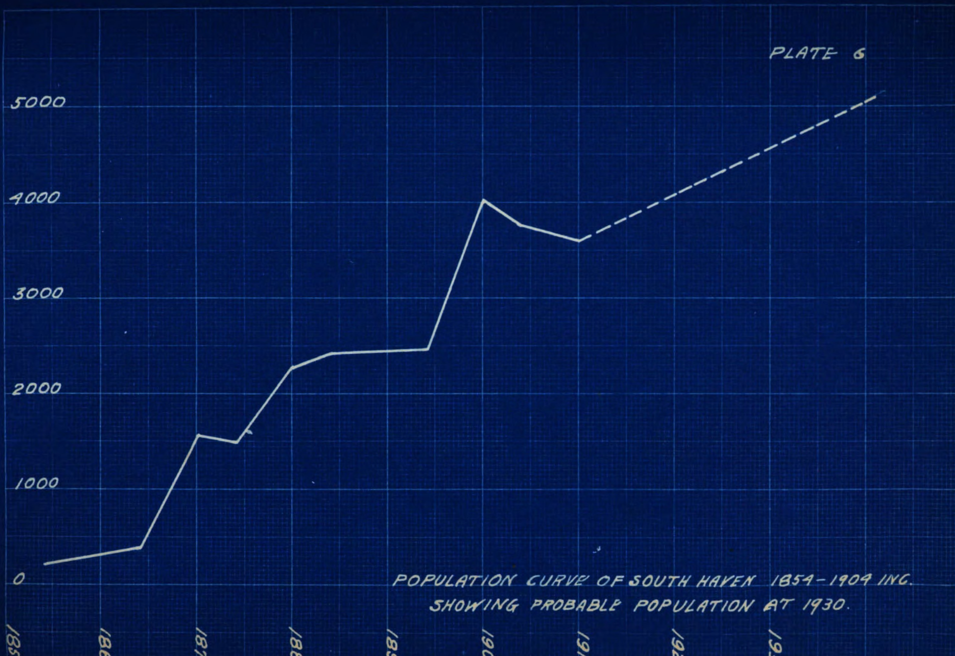


PLATE 6
5000
4000
3000
2000
1000
0
POPULATION CURVE OF SOUTH HAVEN 1854-1909 INC.
SHOWING PROBABLE POPULATION AT 1930.

The maximum daily average for any month is 540,337 gallons. The minimum daily average for any month is 232,048 gallons. The population for the year 1910 from the curve of population is 3700. On this basis the daily average consumption per capita for the year is 316213 ÷ 3700 or 85.5 gallons.

The maximum daily consumption per capita is 540337 ÷ 3700= 146 gallons. The minimum daily consumption per capita is 232048 ÷ 3700 =62.7gallons.

This average daily consumption per capita of 85.5 gallons is a very reasonable quantity. From a table given in Merrimans Public Water Supply, page 34, the average per capita consumption for 100 of the principal cities of the United States and Canada is 105 gallons. For purposes of comparison the following table taken from the same author, is inserted.

CONSUMPTION OF WATER IN AMERICAN CITIES IN 1905.

| CITY | PERCENT OF TAPS METERED | CONSUMPTION PER CAPITA DAILY |
|---|---|---|
| Chicago | ------ | 200 |
| Philadelphia | 1.0 | 230 |
| St. Louis | 7.0 | 92 |
| Boston | 5.0 | 151 |
| Cleveland | 68.0 | 187 |
| Buffalo | 3.0 | 324 |
| San Francisco | 21.0 | 96 |
| Cincinatti | 12.0 | 130 |
| Detroit | 9.0 | 188 |
| Milwaukee | 80.0 | 91 |
| Louisville | 8.0 | 81 |
| Minneapolis | 47.0 | 76 |

| CITY | PERCENT OF TAPS METERED | CONSUMPTION PER CAPITA DAILY |
|---|---|---|
| Providence | 86 | 68 |
| Indianapolis | 10.0 | 82 |
| Kansas City | 38.0 | 73 |
| St. Paul | 38.0 | 56 |
| Rochester | 41.0 | 88 |
| Toledo | 90.0 | 75 |
| Columbus, O. | 76.0 | 110 |
| Aurora, Ill. | 36.0 | 58 |
| Madison, Wis. | 97.0 | 46 |
| Clinton, Ill. | 1.1 | 99 |
| Shenandoah, Ia. | 0.0 | 35 |
| Mellrose Mass. | 5.0 | 112 |

An investigation of this table will show that on an average most of the cities included have a much higher daily consumption per capita, than South Haven. It also shows that those cities having the larger percent of taps metered have a lower average per capita consumption. The largest cities which have such an excessive water consumption per capita have very few taps metered. This shows that there is an unnecessarily large waste of water and the desirability of a metered system. The city of South Haven has 911 meters on the system and for apopulation of 3700 this gives a good mrtered system, there being only comparatively few unmetered connections.

| CITY | PERCENT OF TAPS METERED | CONSUMPTION PER CAPITA DAILY |
|---|---|---|
| Providence | 86 | 68 |
| Indianapolis | 10.0 | 82 |
| Kansas City | 38.0 | 73 |
| St. Paul | 58.0 | 56 |
| Rochester | 41.0 | 88 |
| Toledo | 50.0 | 75 |
| Columbus, O. | 76.0 | 110 |
| Aurora, Ill. | 36.0 | 58 |
| Madison, Wis. | 97.0 | 46 |
| Clinton, Ill. | 1.1 | 99 |
| Shenandoah, Ia. | 0.0 | 35 |
| Mellrose Mass. | 3.0 | 112 |

An investigation of this table will show that on an average most of the cities included have a much higher daily consumption per capita, than South Haven. It also shows that those cities having the larger percent of taps metered have a lower average per capita consumption. The largest cities which have such an excessive water consumption per capita have very few taps metered. This shows that there is an unnecessarily large waste of water and the desirability of a metered system. The city of South Haven has 911 meters on the system and for apopulation of 3700 this gives a good mrtered system, there being only comparatively few unmetered connections.

-- PLANT. --

PUMPING STATION.

The pumping station is located on the shore of the lake about 200 south of the river and about 200 from the waters edge of the lake.

The equipment of the plant consists of the following:

2 -- 150 H.P.Springfield Tubular Boilers 72 x 18.

1 -- 150 H.P.Muskegeon Boiler 72x 18.

1 -- Grand Haven Marine Engine 14 x 12.

(High pressure and direct acting.)

1 -- Gould Triplex Power Pump,direct connected to the above 11x10

( Capacity 750000 gallons per day.)

2 --

2 -- Hughes Duplex High Pressure Pumps 14 x 8½ x 12.

( Capacity 750000 gallons per day.)

The water is obtained from the lake through an intake 20 inches in diameter extending out 2000 feet from the well into which it flows. This well is meant to serve the purpose of allowing the sand and other solid matters to be deposited hence not clogging up the pumps. The well is about 75 feet from the pumps and is connected to them by means of a 22 inch suction pipe. Also a by-pass pipe connects the intake directly with the pumps By closing the valves between the well and this connection the water can be pumped directly from the intake. This has been found necessary due to the fact that the well intake could not furnish enough water into the well when a maximum amount was needed. The difference in elevation between the level of the lake and the inlet to the well,is six feet,when the lake is at zero level.At present the lake is 2.3 feet below zero,leaving a gravity head of 3.7 feet to keep the well supplied with water. Even this reduced head should

furnish enough water as the following computations will show.

Given: D.= Diameter of pipe = 166 feet.

L. = Length of pipe =2800 feet.

H. = Head of water = 3.7 feet.

To find the discharge in gallons per day, Q.

Q =AV , where A is the area of the discharge pipe and V the velocity of the flowing water.

$$V = \sqrt{\frac{2gh}{1.5 + f\frac{1}{d}}} = \sqrt{\frac{2 \times 32.2 \times 3.7}{1.5 + .02 \times \frac{2800}{1.66}}}$$

V = 2.6 feet per second

$A = .7854 \times \overline{1.66}^2$

$Q = AV = .7854 \times 1.66^2 \times 2.6 \times \quad = 0.565$ cu.ft. per second.

$Q = 0.565 \times \frac{800}{107} \times 60 = 255$ gallons per minute.

$Q = 60 \times 24 \times 265 = 3,772,000$ gallons per day.

The maximum daily average of water pumped in July was 485,030 gallons. Hence the shortage is not due to small head, friction, or small pipe Further investigation indicated that the intake had become clogged with sand, leaving but a small portion of the entire opening available for dis charging.

The mouth of the intake consists of a four foot section of pipe twenty inches in diameter placed verticaly as shown in Plate 8. This section is surrounded by a large bell, which is in turn covered by a plate with ¾ inch holes drilled in it. This plate acts as a strainer to keep out fish and any coarse material It is held in place by several bolts and nuts.

Although all the pumps were kept at work the demand for water could not supplied and the pumps were working under a hi h suction head. Upon making a thorough examination of the mouth of the intake the intake by sending down a diver, it was discovered that the cover plate was off and from evidence gathered had been off for years. This gave ample chance for choking the intake so that probably not more than one fourth of the area was left for discharge opening. Then there the possibility that the pipe had settled at some point and broken, allowing the two ends to slide past each other, and thus decrease the area for flow. To determine whether this was true, a centrifugal pump was first placed in the well and attached to the intake inlet and water forced back through the intake, thus partly flushing the sand out. Then an air pump, set up on a dredge, was taken out and attached to the mouth of the intake. By forcing air through it any leak of importance would at once be located by the escaping air. The report of this test carried on by the Board of Public Works says that no leaks were found and from all indications the intake became choked with sand possibly due to the absence of the cover.

To clean out the intake two 7 inch by pass pipes from the main to the suction pipe were put in. Then, having filled the standpipe, the valves were closed shutting off the pumps and the water forced through the intake. This gave the desired velocity of water necessary to clear the intake of some of the collected sand and increased the effective diameter of the pipe. However, even after this flushing, the pumps were running under a head of 10.8 inches of mercury. This means a total lift of 12.2 feet. The lift from the intake to the pumps was 8 feet at the time of this reading, the lake being 8 feet below zero. Hence the equivalent head on the discharge end of the intake is 12.2 feet minus 8.2 feet plus the 4 feet of pressure head making a total head of 8.2 feet.

At the rate of pumping, when the above observations were made, the total number of gallons pumped per day was 900,000. Knowing the head and the length of pipe and assuming the coefficient of friction as 0.02 the diameter of an equivalent area which would supply this quantity can be computed by the folowing formulae.

$$D. = 0.479 \sqrt[5]{\frac{flq^2}{h}}$$

Substituting the given values in this formula,

$$D. = 0.479 \sqrt[5]{\frac{.02 \times 2900 \times 1.32^2}{8.2}}$$

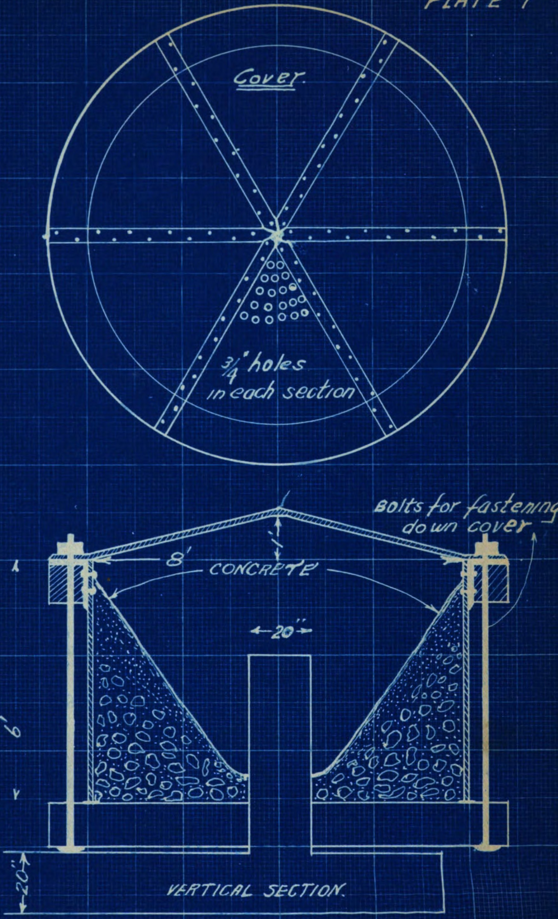
D. = 0.8 feet.

This gives an area of 72.38 square inches. The area of a 20 inch pipe is 314.15 square inches. From this of the total area open for discharge is 72.38 / 314.15 or 23%. From Trautwine page 187 the rise of the segment of the pipe which is open is 5.6 inches or it is safe to say 6 inches on the average. This computation is only approximate but it gives an idea of the condition of the intake pipe. This probable condition is shown diagrammaticaly in Plate 9.

The mouth of the intake is surrounded by an 8 foot boiler plate shell resting on a timber foundation held in place by four piles. A vertical section through it showing a comparative view is shown in Plate 7.

Plate 8 shows a vertical section through both the intake and well. It shows their relative positions and the head which causes the flow into the well.

PLATE 7




Drawing showing general form of mouth of intake

PLATE 8

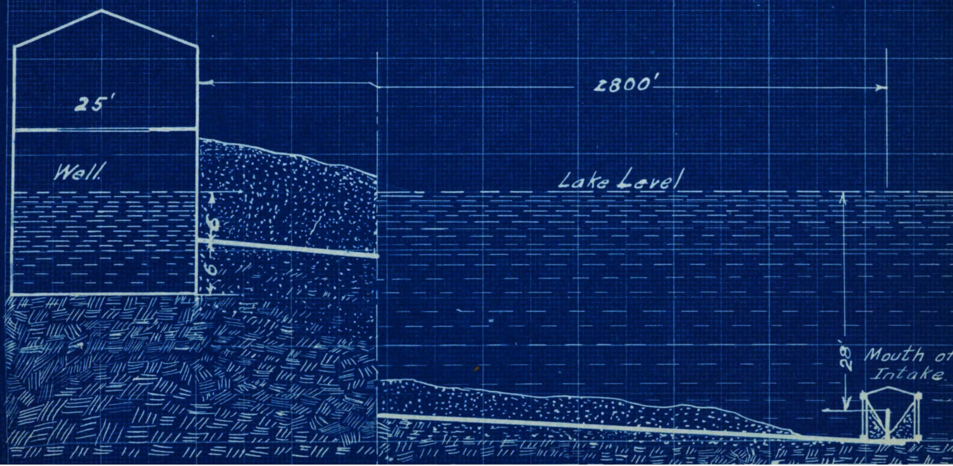
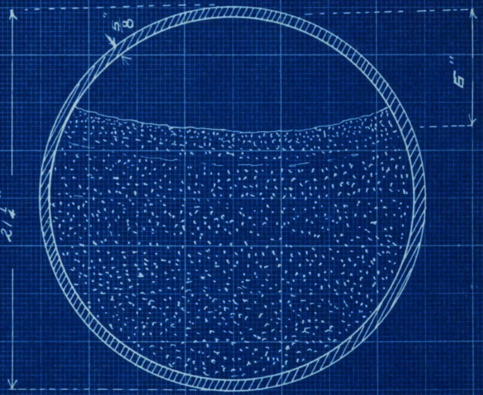


PLATE 9.




PROBABLE CONDITION OF SOME
SECTIONS OF INTAKE PIPE

## RESERVOIR

The stand-pipe is situated on Quaker street about seven blocks from the pumps. The elevation of its base is 35.1 feet above zero, hence the base is 35.1 - 6 = 29.1 feet above the valves of the pump. The height is 100 feet, being built up in 5 foot sections 20 in number, of $\frac{3}{4}$ inch boiler plate. The outside circumference measured 47.8 foot. Then outside diameter equals 15.2 foot and inside diameter 15 feet. The total volume is

$$100 \times \frac{15^2}{4} \times 3.1416 = 17671 \text{ cubic feet.}$$

The pipe rests on a masonary foundation. The top is kept covered by a wooden cover. By referring to the map it will be seen that the standpipe serves merely as an equalizer of pressure. When more water is pumped than is being used the excess goes into the standpipe.

### PIPE LINE SYSTEM.

In order to determine whether the present pipe line system is sufficient to furnish the maximum rate of flow, the sizes of the pipes were computed for several of the large mains and were found to be large enough.

The entire layout is shown on the large map of the city, (found in the pocket of this volume). In order to determine the actual losses of head due to friction in the pipes, gates, valves, and turns, pressures were taken at various hydrants of the city, by attaching a pressure gage to the hydrants. It was not necessary to obtain pressures for each hydrant, but only at every point where size of pipe changes. The gage used was a 100 pound Standard Test Gage. To correct for errors of the gage, the gage was calibrated. The following table shows the results of the calibration test;

## CALIBRATION OF PRESSURE GAGE.

| Weights appl. | Readings (increasing weights) | Readings (decreasing weights) | Average |
|---|---|---|---|
| 5 lbs. | 6.0 lbs. | 6.0 lbs. | 6.0 lbs. |
| 10 | 11.6 | 11.6 | 11.6 |
| 15 | 16.2 | 16.2 | 16.2 |
| 20 | 20.6 | 20.6 | 20.6 |
| 25 | 25.6 | 25.6 | 25.6 |
| 30 | 30.5 | 30.8 | 30.7 |
| 35 | 35.8 | 36.0 | 35.9 |
| 40 | 40.5 | 40.6 | 40.6 |
| 45 | 46.0 | 46.0 | 46.0 |
| 50 | 50.8 | 51.0 | 50.0 |
| 55 | 55.8 | 56.0 | 55.9 |
| 60 | 60.6 | 60.6 | 60.6 |
| 65 | 65.6 | 65.6 | 65.6 |
| 70 | 70.4 | 70.6 | 70.5 |
| 75 | 75.0 | 75.2 | 75.1 |
| 8080 | 80.0 | 80.0 | 80.0 |
| 85 | 85.0 | 85.0 | 85.0 |
| 90 | 89.6 | 89.4 | 89.5 |
| 95 | 94.0 | 94.0 | 94.0 |
| 100 | 99.0 | 99.0 | 99.0 |

These results show the gage to slightly in error at certain pressures, hence the pressures obtained from the hydrants must be corrected byv the amount the gage is off at that pressure. In the table given on the following page are recorded in first column, the pressures in pounds per square inch; In the second column, the readings after having been corrected for errors of the gage; in the third column, the elevations above zero of the street intersections as obtained from the notes recorded by the City Engineer.

PRESSURES AND ELEVATIONS AS TAKEN AT THE FOLLOWING STREETS.

| STREETS | OBSERVED PRESSURES | CORRECTED PRESSURES | ELEVATIONS ABOVE ZERO |
|---|---|---|---|
| Center & Quaker | 36.0 lbs. | 35.2 lbs. | 38.5 |
| " " Michigan | 30.4 | 29.7 | 39.8 |
| " " Green | 31.0 | 30.3 | 38.0 |
| " " Phoenix | 30.6 | 29.9 | 40.2 |
| P<br>Phoenix" Broadway | 31.0 | 30.3 | 38.6 |
| " " Pearl | 31.2 | 30.5 | 37.59 |
| " " Bailey | 29.0 | 28.3 | 44.15 |
| " " Kalamazoo | 35.0 | 34.1 | 35.4 |
| " " Cherry | 26.0 | 25.4 | 50.2 |
| Broadway & Green | 30.1 | 29.3 | 38.1 |
| Pearl " Erie | 29.0 | 28.3 | 43.8 |
| LeGrange " Philips | 27.0 | 26.5 | 44.5 |
| Cherry " Superior | 20.0 | 19.4 | 52.0 |
| Bailey " Conger | 30.0 | 29.3 | 37.13 |
| Kalamazoo" Michigan | 28.4 | 27.7 | 33.3 |
| St. Joe " " | 32.0 | 31.5 | 33.9 |
| " " Elkenburgh | 29.6 | 28.9 | 23.4 |
| South Haven & Maple | 30.4 | 29.7 | 42.0 |
| Lake " Dyckman | 38.0 | 37.4 | 26.6 |
| " " River | 48.0 | 47.0 | 4.5 |
| " " Wells | 37.0 | 36.4 | 32.6 |
| " " Base Line | 34.0 | 33.1 | 42.1 |
| Dyckman " Main | 38.0 | 37.4 | 16.04 |
| " " Williams | 46.0 | 45.0 | 10.0 |
| Main " Wells | 38.0 | 37.4 | 26.6 |

Computations showing method of applying corrections to gage readings. In taking the gage pressure at the pumping stat[illegible] it was found that the gage in the plant was in error.

Reading of plant gage 39 pounds.

Hydrant pressure at plant by test gage ----------43.4

Difference in elevation between hydrant and gage in the plant----[illegible]

Difference in elevation reduced to pounds--$2\frac{1}{4}$ x .434 = 1.75 pounds.

Reading of plant gage reduced to levelof hydrant--39.0 + 1.75 =40.7[illegible]

Error of plant gage-- 43.4 - 40.75 = 2.65 pounds.

That is this gage reads 2.65 pounds low, or final correcto[illegible] reading of pressures at the pumps is 39.0 + 2.65 = 41.65 pounds, as taken in the forenoon.

Reading of pressure at pumps in the afternoon was 41 pound[illegible] Applying the correction of 2.65 pounds, the reading was 43.65 ". Hence to reduce the afternoon pressures to basis of forenoon pressu[illegible] subtract from each afternoon reading the difference between 43.65 and 41.65 or 2 pounds.

In the table on page 48, are given in the first column, the corrected gage readings, having been corrected for errors in test gage and difference in pressure between afternoon and forenoon, readings. The second column gives these pressures expressed in feet of pressure head. The third column gives the elevation of the streets intersections, taken near the hydrants and on the surface of the pavement, plus the two feet rise of the hydrant top above the surface. This elevation plus the pressure head, given i in column two, gives the head above zero at that point, as shown in column four; Knowing the pressure head at the pumps, above zero, the lost head due to valves, turns, etc.,is found by taking the difference between them, which is recorded in column five. By assuming the pipes to be laid parallel to the surface and at a uniform depth no account was taken of the depth below the surface as the lost head was then the same as assumed above.

EXAMPLE:

Observed pressure at Center& Quaker-------------36 pounds.

Correction for error in gage -------------------(-.8 " )

Corrected reading-------------36 - 0.8 = 35.2 pounds

As this is an afternoon reading subtract 2 pounds or the reduced reading is ------------- -------- ----35.2 - 2 = 33.2 pounds.

From formula, head equals 2.304 x pressure.

H = 2.304 x 33.2 = 76.4 feet

Elevation of hydrant----------- 32.5 feet

Total head in feet above zero lake level is 76.4 + 32.5 = 108.9 feet.

Head above zero at standpipe is 109.25 feet.

Loss of head between pump and hydrant at Center & Quaker is 109.25 - 108.9 = 0.35 feet.

Head of water in standpipe above zero in the forenoon.

Elevation of bottom of standpipe ---31.5 feet.

" " hydrant at Center & Phoenix----40.25 feet.

Difference in elevation -------------- 8.75 feet.

Pressure head at Center & Phoenix --------69.0 feet.

Hence height of water in the standpipe during the forenoon was

69.0 + 8.75 = 77.75 feet .

Head of water above zero----77.75 + 31.5 = 109.25

Since all afternoon pressures readings are reduced to forenoon pressures by deducting two pounds the head in the standpipe in the afternoon need not be used for computing lost heads.

TABLE SHOWING LOST HEADS AT POINTS WHERE PRESSURES WERE TAKEN.

| STREETS | REDUCED READINGS | HEAD IN FEET | ELEV. | HEAD ABOVE ZERO | LOST HEAD |
|---|---|---|---|---|---|
| Gen. & Quaker | 33.2 # | 76.4 ft. | 32.5 ft. | 108.9 ft. | 0.[illegible] ft. |
| " " Mich. | 29.7 | 68.5 | 39.8 | 108.3 | 0.95 |
| " " Green | 30.3 | 70.0 | 38.[illegible] | 10[illegible].0 | 1.2[illegible] |
| " " Phoenix | 9.9 | 9.0 | 40.25 | 109.25 | 0.00 |
| Broadway & " | 30.3 | 70.0 | 38.6 | 108.6 | 0.65 |
| Pearl " " | 30.5 | 70.4 | 37.50 | 107.90 | 1.[illegible] |
| Bailey " " | 28.3 | 65.2 | 44.15 | 109.35 | -0.1 |
| Kalamazoo " " | 32.1 | 73.8 | 35.4 | 109.2 | .05 |
| Cherry " " | 25.4 | 58.6 | 50.25 | 108.85 | 1.00 |
| Broadway " Green | 29.3 | 67.6 | 40.1 | 107.7 | 1.[illegible] |
| Pearl " Erie | 28.3 | 65.2 | 45.8 | 110.0 | -1.75 |
| LaGrange " Phil. | 26.3 | 60.8 | 46.5 | 107.1 | 2.15 |
| Cherry " Super. | 19.4 | 44.7 | 54.0 | 98.7 | 10.[illegible] |
| Bailey " Conger | 29.3 | 67.6 | 39.13 | 106.73 | 2.[illegible] |
| Lake " Mich. | 27.7 | 63.7 | 35.3 | 99.0 | 10.[illegible] |
| St.Joe." " | 31.3 | 72.2 | 35.9 | 108.1 | 1.15 |
| " " Holcomb. | 28.9 | 66.6 | 43.4 | 110.0 | -.75 |
| S.Haven" Maple | 29.7 | 68.5 | 39.0 | 107.5 | 1.75 |
| Lake St." Dyck. | 35.4 | 81.5 | 27.6 | 109.1 | .15 |
| " " River | 45.0 | 103.5 | 4.5 | 108.0 | 1.25 |
| " " Wells | 34.4 | 79.2 | 32.6 | 111.8 | -2.5[illegible] |
| "" " B.L. | 31.1 | 71.6 | 42.1 | 113.7 | -4.45 |
| Dyck. & Main | 35.4 | 81.6 | 18.4 | 99.9 | 9.35 |
| " " Williams | 43.0 | 98.9 | 10.0 | 108.9 | 0.35 |
| Main " Wells | 35.4 | 81.5 | 26.6 | 108.1 | 1.15 |

Computation for size of main from Power House to Kalamazoo Ave

In computing the size of pipe necessary to supply a certain district or town, the maximum average consumption must be obtained, or assumed. Then since more water is used in the mornings and evenings for domestic purposes, and on Mondays, as wash day, the rate of flow willbe considerably higher. Practice has determined it as 175% of the maximum average daily consumption per capita. Also the pipe must be designed to furnish "n" number of fire streams at one time, where "n" is obtained by the formula given on page 743 of "Public Water Supplies" by Turneaure and Russel:

$N = 2.8\sqrt{x}$ where x = population in thousands; each fire-stream to deliver 200 gallons per minute. Then the total rate of flow will be the sum of these two ot:

Maximum rate of flow = 175% x maximum average daily consumption per capita + flow from "n" fire streams at 2'0 gallons per minute.

Assumed maximum average consumption per capita per day = 85 gal.

175% of 85 = 150 gallons per capita.

Population for the future at 1930 is assumed as 5500, hence the total consumption at that time would be 1500 x 5500 = 850,000 gallons per day.

$$Q = \frac{825,000}{60 \times 24} = 573 \text{ gallons per minute.}$$

For the number of fire streams, $N = 2.8 \times 5.5^{\frac{1}{2}}$

N. = 6, the number of fire streams.

Each stream delivers 200 gallons per minuteand thus the total consumption will be 573 + 1200 = 1,773 gallons per minute or 29.6 gallons per second. This reduced to cubic feet per second gives a required supply of 3.96 cu. ft. per sec.

From Merrimans Treatise on Hydraulics the following formula for the computation of the size of a pipe, page 227.

$$D. = 0.479 \left(\frac{flq^2}{h}\right)^{\frac{1}{5}}$$

In which, f = coeffficient of friction  l = length of pipe.

q = cubic feet per second.  h = head lost in length "l".

For first computation assume f = .02 also let l = 1800 feet.

q = 3.96 cu.ft.  h = 10.25

Then $D = 0.479 \left(\frac{.02 \times 1800 \times 3.96^2}{10.25}\right)^{\frac{1}{5}} =$ 12.9 inches.

This size of pipe will be necessary when the population reaches to five or six thousand inhabitants, in orderto supply the water economicaly, and not use up the power for obtaining higher pressures.

The size of the present main is 10 inches which is sufficient. All the other pipes of the system are of sufficient size since none are required greater than the 10 inch and the smallest size allowed is 4 inches which is only used in the scattered district. Also the maximum loss of head being 11 feet would indicate that plenty of water is being supplied; that is there is very low velocity hence small loss due to velocity and friction.

To show graphicaly the losses of head at the various points in the pipe line system, the profiles of each street are plotted, elevations being refered to zero lake level. From same datum plane plot the actual pressures obtained at the hydrants after reducing to zero level. Also plot lines showing actual head above zero at the standpipe. By connecting the pressure heads of the hydrants there is obtained a curve known as the Hydraulic Gradient which is the line to which the water level would rise if piezometer tubes were inserted at these points. If the pipe lines are laid approximately horizontal this line would

be straight. When pipes are laid in sharp vertical curves the gradient will fall below the pipe, when acts as a siphon. This should be avoided. In the accompanying plates are shown the hydraulic gradient showing the losses of head at several points of each street. See plates 11, 12, and 13, & 10

The following is a table showing the number of feet of the several sizes of water mains in the city.

WATER MAINS.

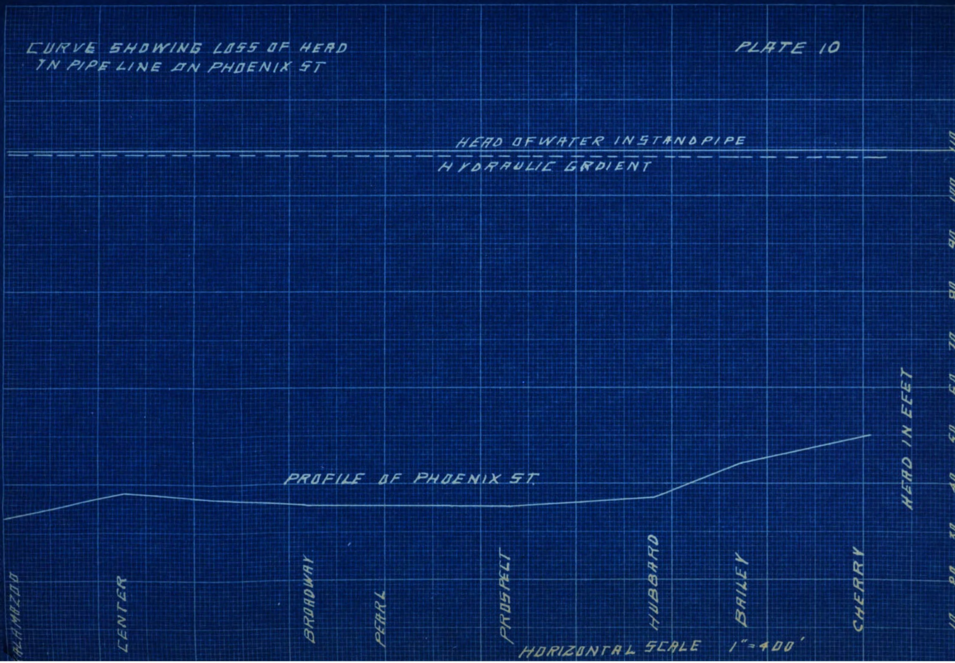
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 400 | feet | of | 2" | wrought | iron | pipe, | |
| 1 5 | | | | | | | |
| 1 500 | " | " | 2½" | " | " | " | |
| 17 640 | " | " | 4" | cast | " | " | |
| 27 800 | " | " | 6" | " | " | " | |
| 4 000 | " | " | 8" | " | " | " | |
| 22 200 | " | " | 10" | " | " | " | |

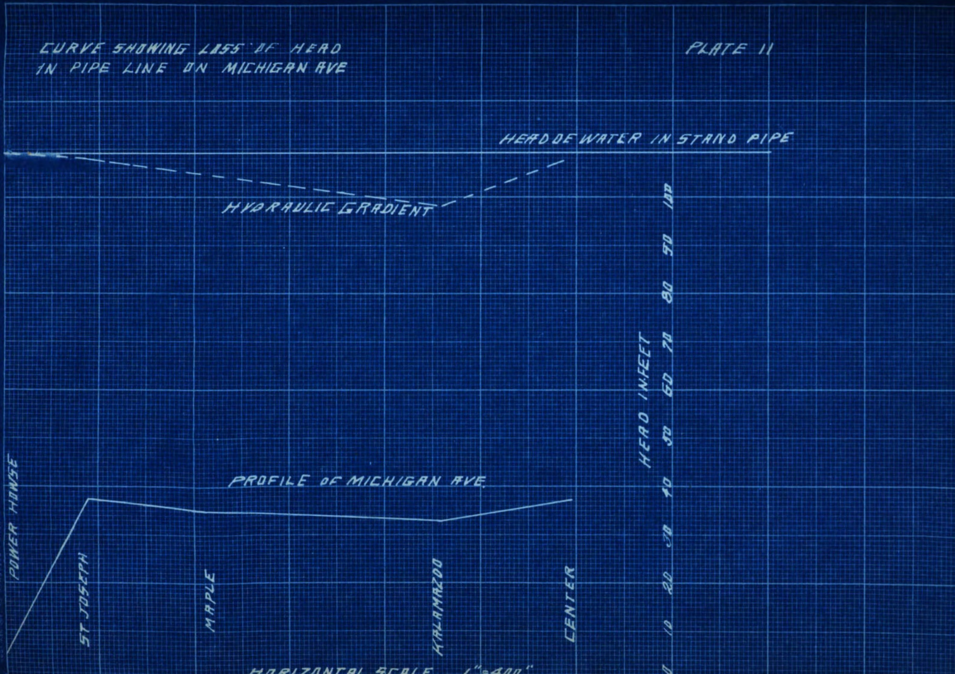
The city is divided into three sections, A, B, and C, and the following table shows the number of each size of meters at present installed in each section.

WATER METERS.

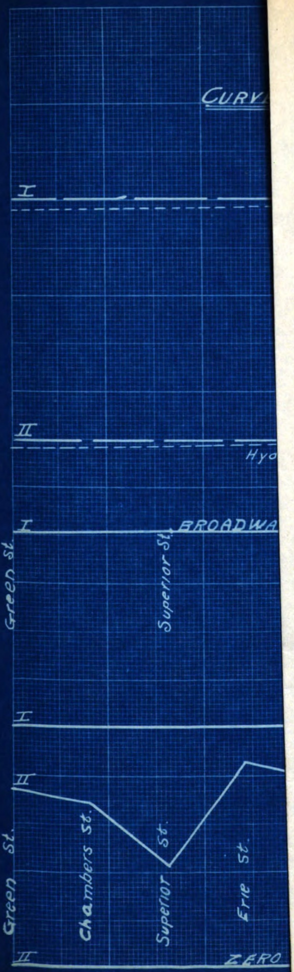
| Sizes. | 5/8" & 3/4" | 1" | 1½" | 2" | 4" |
|---|---|---|---|---|---|
| Sect. A. | 308 | 3 | 0 | 2 | 0 |
| Sect. B. | 340 | 3 | 0 | [illegible] | 0 |
| Sect. C. | 229 | 10 | 1 | 1 | 1 |
| Special Service | 12 | 7 | 1 | 2 | 0 |
| Total | 879 | 23 | 2 | 6 | 1 |

Total meters installed - 911.


CURVE SHOWING LOSS OF HEAD
IN PIPE LINE ON PHOENIX ST
PLATE 10
HEAD OF WATER IN STANDPIPE
HYDRAULIC GRADIENT
PROFILE OF PHOENIX ST.
HEAD IN FEET
110
100
90
80
70
60
50
40
30
20
10
KALAMAZOO
CENTER
BROADWAY
PEARL
PROSPECT
HUBBARD
BAILEY
CHERRY
HORIZONTAL SCALE 1" = 400'



CURVE SHOWING LOSS OF HEAD
IN PIPE LINE ON MICHIGAN AVE
PLATE 11
HEAD OF WATER IN STAND PIPE
HYDRAULIC GRADIENT
PROFILE OF MICHIGAN AVE.
HEAD IN FEET
0
10
20
30
40
50
60
70
80
90
100
POWER HOUSE
ST JOSEPH
MAPLE
KALAMAZOO
CENTER
HORIZONTAL SCALE 1"=400'


CURV
I
II
Hyd
I BROADWA
Green St.
Superior St.
I
II
Green St.
Chambers St.
Superior St.
Erie St.
II
ZERO

## FIRE PROTECTION.

Fire hydrants must be of such a number and so located as to make it possible to concentrate two-thirds of the number of required fire streams simultaneously an any one square. If 'y' is the number of fire streams to be furnished at any one time for the entire city, by Fuichling's formula, $y = 2.8\ x^{1/2}$, where 'x' is the population in thousands. In this case $x = 5.5$ there fore $y = 2.8 \times 5.5^{1/2} = 6$ fire streams.

For residence sections, one-fourth of the total number, or two fire streams is sufficient. According to Freeman, two-thirds of the total number are required for any one square of the compact business section. This gives four as the required number of fire streams for the business section.

Hydrants should not be so far apart as to require more than five hundred feet of hose. Friction in the hose greatly reduces the available head. By examining the map for the location of the various hydrants, it is found that the above requirements are met. There are 108 fire hydrants, nearly all of which are of the two-way type. The pressure used during a fire is obtained by shutting off the stand pipe and increasing the pressure of the mains by auxillary pumps.

## FLUSHING.

While obtaining the data for this thesis, the problem came up of how to thoroughly flush all the mains of the city, and to do it effectively. It was very evident that the pipes needed cleaning, for while obtaining hydrant pressures the water was turned on fully ten minutes at the corner of Kalamazoo St., and Michigan Ave., and at other points for five minutes before the water cleared up. The first gush of water was rusty and rediah brown in color. After the rusty color creared up, the water appeared muddy. This would indicate that the mains are lined with fine deposits of clay, sand, and sediment of most any sort, and when flushed out, these deposits are stirred up, and carried along by the increased velocity. To do any effective flushing, the water must have quite high velocity, and to get this, the flushing must be done in sections. This can be done by closing the gates of all lines except one, and opening the hydrants at the end of this line. By increasing the pressure at the pumps, and gating down the mains to straight lines, open at the farther end, the sedimend will be washed loose, and carried out of the mains. However, as the workmen of the city report, that most of the gate valves are out of repair it will be impossible to do any real effective flushing. Under such conditions it would be adviseable to repair these valves as soonass possible. In the mean time flushing by opening the hydrants at various points in the city would be better than not flushing at all.

FINANCES

FIRST COST.

The actual cost to the city of the water works plant to March 1st 1908 according to the City Clerks books is $60,000.00

Inventory March 1st 1907 by L.A.Bridges, Supt.of Public Works.

WATER WORKS.

| | |
|---|---|
| Building | $ 5300.00 |
| Land | 800.00 |
| Intake (new) 20" | 20000.00 |
| 2 old pumps | 300.00 |
| 1 New Triplex pump | 1350.00 |

| | | |
|---|---|---|
| Boilers | $ 2,000.00 | |
| Stacks | 140.00 | |
| Condenser | 100.00 | |
| Condenser suction | 100.00 | |
| Steam pressure gages | 75.00 | |
| Tools | 25.00 | |
| Mains | 22,672.00 | |
| Standpipe | 3,000.00 | |
| Meters 540 | 2,000.00 | |
| Small pipe & Hydrants | 4,750.00 | $ 63,012.00 |
| Depreciation according to this inventory, | | 23,074.00 |
| | | $ 06,986.00 |

BALANCE SHEET AND STATEMENT for fiscal year ending March 1st 1911.

| | | |
|---|---|---|
| Value of plant as represented by out standing bonds and indebtedness, | $ 68,[illegible].94 | |
| NEW CONSTRUCTION | | |
| Power House | 24.[illegible] | |
| Office equipment | 57.20 | |
| Broadway St. stubs | 172.[illegible]2 | |
| " " labor | 185.[illegible] | |
| New meters | 2,380.00 | |
| Meter box tile | 344.25 | |
| Tile covers | 308.46 | |
| Pipe fittings | 559.08 | |
| Labor installing | 639.20 | $ 70,972.20 |

| | | |
|---|---|---|
| Material sold | $ 10.50 | |
| Depreciation | 2,347.42 | |
| Present book value | 68,621.28 | $ 70,979.20 |

Present book value March 1st 1911, $ 68,621.28.

DEPRECIATION

The depreciation is estimated on the following basis by the Board of Public Works for the fiscal year ending March 1st 1911.

| EQUIPMENT | ESTIMATED VALUE | RATE OF DEPRECIATION | DEPRECIATION |
|---|---|---|---|
| Power House | $ 7,375.00 | 6% | $ 442.50 |
| Intake | 15,000.00 | 2% | 300.00 |
| Building | 2,500.00 | 4% | 100.00 |
| Pipe line | 34,746.00 | 2% | 694.92 |
| Meters | 9,000.00 | 8% | 720.00 |
| Stand Pipe | 3,000.00 | 3% | 90.00 |
| | | | $2,347.42 |

OUTSTANDING BONDS.

| DATE PAYABLE | AMOUNT. |
|---|---|
| 1911 | $ 2,000.00 |
| 1912 | 2,000.00 |
| 1913 | 2,000.00 |
| 1914 | 2,000.00 |
| 1915 | 2,000.00 |
| 1916 | 2,000.00 |
| 1917 | 7,000.00 |
| 1918 | 5,000.00 |
| 1920 | 3,000.00 |
| 1931 | 18,000.00 |
| 1937 | 20,000.00 |

PAYMENT OF FIRST COST.

The method of payment of the first cost has been by the issuing of bonds as will be seen by the above table the date of payment of the bonds has been scattered through the various years, with the exception of the last two, due respectively in 1931 and 1937. It was expressed as the probable policy in regard to these that at, the time of their maturity they would be taken up and reissued and made payable at intervals in the future the same as the proceeding issues. No provision for a sinking to meet these bonds at maturity has been made. The only method of taking into consideration the decreasing value of the plant or its replacement is the charging of an annual depreciation according to the schedule given previously.

INSURANCE

Insurance is carried as follows,

| | |
|---|---|
| On Power House and Equipment | 10000.00 |
| On Work Shop | 1000.00 |
| On Boilers | 20000.00 |
| Total | 31000.00 |

This includes both water plant and electric light plant. It is estimated that two thirds of this applys to the lighting plant and one third to the water plant.

RATES

The following schedule of water rates is in effect in the city:

| | | |
|---|---|---|
| 1st. | 2000 gallons or less | $0.28 per 1000 gallons. |
| 2nd. | " " " " | 0.25 " " " |
| 3rd. | " " " " | 0.22 " " " |

4

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 4th. | 2000 gallons or less | | | | [illegible] | per 1000 gallons. | | |
| 5th. | " | " | " | " | 0.15 | " | " | " |
| | ------------------- | | | | | | | |
| 2nd | 10000 | " | " | " | 0.16 | " | " | " |
| 3rd. | " | " | " | " | 0.14 | " | " | " |
| 4th. | " | " | " | " | 0.12 | " | " | " |
| 5th. | " | " | " | " | 0.10 | " | " | " |
| | ------- --------- -- | | | | | | | |
| 2nd. | 50000 | " | " | " | 0.09 | " | " | " |
| 2nd. | 100000 | " | " | " | 0.08 | " | " | " |
| Next | 50000 | " | " | " | 0.07 | " | " | " |

All water in excess of 250,000 gallons furnished quarter yearly----- ------------------------ -0.06 per 1000 gallons.

Water meter rent is charged whether service is used or not. All charges for water and meters should be against the service and not against the individual. The minimum charge for water shall continue unless we have orders to cut off the water.

To accounts not paid in ten days from date of invoice, ten percent will be added, and if not paid within twenty days service will be discontinued.

The city is divided into three sections: A, B, and C. Section A includes that part of the city south of Phoenix and andwest of Center streets, and bills for that part of the city are sent outb March 15, June 15, September 15, and December 15, respectively.

Section B is that part of the city south of Phoenix and east of Center streets and bills are sent out January 15, April 15, July 15, and October 15, respectively.

Section C is that part of the city north of Phoenix St. and bills are sent out February 15, May 15, Aug. 15, and Nov. 15.

Cost of pumping water for fiscal year ending Mar. 1, 1911.

Total water pumped------------------------------116,418,270 gal.

| | TOTAL COST. | COST PER 1000 " |
|---|---|---|
| Coal | $ 2385.86 | $ 0.0206 |
| Power Repairs and Supplies | 888.11 | 0.0076 |
| Engineer and Firemen | 1224.75 | 0.0105 |
| Line Repairs and Maintenance | 1052.70 | 0.0090 |
| Intake Repairs | 17[illegible]1.89 | 0.0154 |
| General Expense | 600.31 | 0.0051 |
| Interest and Depreciation | 5417.42 | 0.0465 |
| TOTAL---------- | 13371.02 | 0.1147 |

REVENUE FROM WATER RATES.

| | | |
|---|---|---|
| Water rents | $ 9[illegible]95.75 | |
| Water for flushing sewers | [illegible].18 | |
| Water to the city | | |
| Watering troughs | 381.04 | |
| Public buildings | 40.77 | |
| Street sprinkling | 819.00 | |
| Fire protection, 102 fire hydrants at $ 25.00 | 2550.00 | |
| | | 13681.74 |
| GAIN | 310.72 | |
| TOTAL COST | 13371.02 | 13681.74 |

Conclusions drawn from preceding data and recommendations based on the same.

The same general outline will be followed in setting forth these recommendations as in the discussion of the data. Therefore the first item will be the source of the water supply. At first thought it would seem that there could be no better supply of water than that of Lake Michigan. There seems to be an unlimited quantity of clear, cool, pleasant tasting water but unfortunately there are serious difficulties to be met in obtaining it. Nearly all the cities which obtain these supply thus are located near some river into which their sewage is discharged often with entire disregard to the pollution of their water supply. In this case the intake lies only 138 feet to the south of the river and only 200 feet from the effective mouth of the river. The natural currents being in a southerly direction, carry this polluted water towards the intake crib. If it were practicable to extend the intake far enough into the lake it will be possible to obtain a satisfactory water but the expense of such an undertaking would be beyond the means of a city of the size of South Haven. From the results of the analyses of water taken 20000 feet farther out, it is plainly seen that no appreciable benifit would be derived and some conditions of weather it is even worse. This is due no doubt to the currents set up by the wind, combined with those due to temperature changes and the current from the river. Little is known about these currents and their action can only be determined by a continued series of observations.

It is unfortunate that the water works plant should have been loc ted at its present position. A distance of one half mile farther north would, without doubt, have given a much better quality of water. The cost of rebuilding at such a point would however put this out of the question entirely. In looking over the possibilities of another source it has been suggested that deep wells might be used. The geological formation however seems to be such that there is no deep ground water available. At different times wells have been driven by private parties to depths beyond the possibility of a city supply and yet found no water. Whereever water is found it seems to be impregnated with undesire-able chemicals. Wells of this type are not to be considered as a source of supply. Another suggestion has been to dig shallow wells on the beach and get water which has percolated through the sand. This we think to be out of the question because of the shallow layer of the sand and the uncertainty of the water being sufficiently purified by this process. It is also doubtful whether a sufficient quantity could be secured in this way.

In general there seems to be three ways of remedying the existing conditions: First, to go far enough into the lake to obtain the desired quality of water; second, to purify the sewage before discharging into the river; third, to purify by filtration or to disinfect the present supply. These will be taken up in detail in the following paragraphs.

The impracticability of the first has been partly shown. The first cost of the present intake, extending as it does 2800 feet into the lake, was 20000 dollars. One of the large lake construction companies as offered to extend the present line

2000 feet farther at the rate of 12 dollars per foot, or for an extension of this length a total cost of 24000.00 dollars. This distance,however, is to short to make certain a safe supply of water. The analyses show that under a considerable number of weather conditionsthe water is as badly contaminated at that point as at the present position. It would probably need an extension of one mile to remove the possibility of occasional times of pollution. This would render the cost prohibitive.

The second method, or the purification of the sewage, also presents several difficulties. In order to understand these, a short discussion of the different methods of sewage purification will be given. The mostly widely practiced method of sewage disposal is dilution,that is the sewage is diluted with sufficient water to carry it to the nearest stream where it is discharged. The natural processes of purifimation then after a time reduce it to harmless compounds . This however takes longer then is generaly supposed and the presence of specific disease germs increase the danger of contamination of the water supply. There are two general objects in the purification of sewage, 1; to remove the solid matter and thus prevent an offense to sight and smell of the stream into which it is discharged; 2 , to reduce it to harmless compounds and distroy the disease bacteria which it may contain and thus remove the danger of polluting the water supply.

The means employed to accomplish this are usualy screening,sedimentation with or without chemicals,septic tanks,filter beds,and irrigation. By screening and sedimentation only the first object isattained and the danger to the water supply is not materialy reduced. For this reason these will not be con-

sidered further. Irrigation consists of allowing the sewage to flow over large areas and in some cases using it to irrigate growing crops. This would not be practicable, due to climatic conditions, the lack of sufficient unocculied land, and the topographic features of the city, and will not be considered further. For similar reasons filter beds would not solve the difficulty. In order to collect the sewage at one plant it would be necessary to pump part of it across the river which would be quite expensive. This limits the field to septic tanks and one othermeans which was not mentioned ,namely the dis infecting of the sewage.

The septic tank is a concrete reservoir through which the sewage and subjected to the action of certain bacteria. It should be of a capacity sufficient to hold 24 hours flow. The sewage flows in at the top, near the upper end and slowly through the tank to the lower end. Due to decrease of velocity all the solid matter settles and is acted upon by certain forms of bacteria which liquify it. These tanks are covered and the outlet is arranged so that only liquid matters pass out at the lower end. The velocity of flow is checked by baffle walls across the tank and extending nearly to the surface. Acertain amount of sludge or solid matter gradually accumulated at the bottom and must occasionaly be removed. Contrary to the general idea the liquid flowing out is not purified and may still contain pathogenic bacteria which make it a source of danger to the water supply. The following paragraph quoted from Kinnicut, Winslow & Pratt's Sewage Disposal PAGE 144 bears this out. "

"The opinion that septic action destroys pathogenic

bacteria has been occasionaly expressed by various observers. This is true only to a limited degree, and no reliance should be placed upon such action where sewage is to be purified with a view to protecting a water supply."

Thus it is seen that a septic tank treatment must be followed by filtration, disinfecting or other means of purification. The most practicable means of disinfecting sewage is by Chlorine from chloride of lime. It is more difficult to disinfect crude sewage owing to large particles which will not be penetrated by the disinfectant and in order to break these up, the sewage must be passed over screens upon which jets of water are playing. The effluents from septic tanks are more eaisly treated since all the solid matter has been liquified. The addition of 75 parts of bleaching powder to a septic effluent, per million gallons has been known to reduce the bacterial content 98%. 75 parts per million gallons would represent about 625 pounds of bleaching powder. For South Haven the daily flow may be estimated at 300,000 gallonsand for the treatment would require 200 pounds of chloride of lime at a cost of say $2.25 per day for chemicals. In regard to the cost of septic tanks several examples are given.

A tank at Lake Forrest Ill., capacity 200,000 gallons per day cost $8,000. One at Wauwatoso Wis. handling 100,000 gallons per day cost $5,370. From this a rough estimate of the cost of a tank of 300,000 gallons capacity would be $ 12,000. The cost of a disinfecting plant to accompany this would not exceed $ 500. making a total cost of $ 12,500. The cost of disinfecting has been estimated at $ 9.00 per 1,000,000 gallons of septic sewage or an average of $3.00 per day.

It is believed that if sewage purification was intended, that the septic tank and disinfecting would be the most practicable for South Haven. This would not however protect the water supply, as all the bacteria cannot be removed, and besides the intake of the water system, lying in the path of navigation is liable to occasional polution. If for instance, a convalescent typhoid patient should be on board some vessel, the danger might be serious. For this reason it is believed that the better method is ti purify the water supply, rather than the sewage. Hazen, in his book, "Clean Water and How to Get It," states that "he believes that one dollar spent in water purification is as good as ten dollars spent in sewage purification." This leaves only thr last remedy, that of purifying the water. A brief outline of the methods of accomplishing this will be given before taking up the recommendations for the particular case in hand.

THE PURIFICATION OF WATER.

In the purification of water reference is usually made to water supplies intended for domestic uses. It may however be considered to apply to other supplies as well, as for example, the water used for manufacturing purposes. For this purpose water should be soft and free from organic and mineral substances, which form objectionable scale in boilers. For breweries, sugar and starch factories, a water free from bacteria should be provided, and in die factories, laundaries and such plants, water free from iron should be obtainable. The main object, however, in water purification, is to obtain a supply suitable for household purposes and for drinking. In household uses, alkali and hard waters are not suitable since the chemical constituents hinder the cleansing action of soap. The purification of such waters therefore becomes an economic feature.

The purifying of water for a potable supply includes two objects. The most important of these is to secure a supply free from pathogenic bacteria and the other to obtain a water pleasant to the taste, clear and sparkling to look upon, and free from objectionable odors. To the common observer the latter is often the more important.

The source from which water will need purification is in general, surface water, which is poluted from contact the surface. Ground waters as a rule, do not need it, as they have been purified by natural means. There are three general means of purification, which may be employed singly or in combination. They are sedimentation, filtration and aeration. They are used to remove suspended impurities from the water. To remove the desolved impurities, another method is resorted to. This is the addition of a chemical which will precipitate the undesirable elements, and then removing them by one or more of the above methods. To remove bacterial impurities another method is sometimes used, namely sterillization.

Sedimentation is one of the first methods to be used. Surface waters, especially those from swiftly flowing streams contain more or less earth or clay in a finely divided condition. These particles are carried along by the current until some lageg large body of water where they settle due to their difference in specific gravity. Natural sedimentation takes place in lakes,

and ponds and its effectiveness is shown by the clearness of the water as compared to the turbidness of the streams by which they are fed.

Artificial sedimentation is obtained by storing the water in large reservoirs and reducing the motion, thusallowing the sediment to settle by its own weight. The longer the water can be stored the better the results will be. A large reservoir also allows the water to be shut off during periods of high water, when the quantity of suspended matter is high. A large number of bacteria are also carried down by the suspended matter, but these only collect on the bottom and growth may take place there. If there is much present besides inorganic matter a satisfactory supply can rarely be obtained by sedimentation alone. The time required for sedimentation to take place varies with the nature of the suspended matter. Some waters require only a few hours or days, while others may require months even months to secure a satisfactory degree of purification.

Sedimentation is carried on in two ways. Either plain or with the addition of a coagulant chemical is used. Itmay be carried on continuously or intermittently. In the continuous system the water flows through a series of settling basins with such a low velocity that the suspended matter has time to settle. The raw water flows in above and the putified water out below. The operation is continuous, the head is constant and the results are practicaly as good as in the intermittent system.

Along with sedimentation a coagulant is sometimes used. This consists in adding a coagulant chemical such as Sulphate of Alumina or Ferric Hydrate to the water before sedimentation. These chemicals form a bulky gelatinous precipitate which settles and

and carries with it the suspended matter and a large part of the bacterial content of the water. The only objection to these chemicals is that the acid left in the water increases the corrosive action on the pipes. The addition of a coagulant retards the subsidence of the suspended matter so that a longer time is required to complete the process. On this sedimentation with a coagulant is usualy preliminary to filtration.

There are two methods of filtrations, the slow sand and the rapid mechanical filter. The principal difference is in the rates at which they are operated. The first is operated at the rate about 3000,000 gallons per day and the other at about 100,000,000 gallons per acre per day. The first sand filters were used in London about 1830. the cheif object at that time was to remove the turbidity of the water supplied to the city fom the Thames river. It is only recently that this method has received its deserved attention in this country. The slow sand filters are large reservoirs having a tight bottom on which is laid a system of drains of vitrified tile. Above these is a layer of broken stone in graded sizes and a layer of fine gravel. The depth of the stone is from 2 to 3 feet. On the stone is placed a layer of from 2 to 5 feet of sand. This bed of sand is the true filter. The water is pumped on to this sand and flows through it by gravity into the system of drains and to the clear well from which it is dis tributed. As the filter continues in operation the rate of flow decreases until a certain fixed head is reached when the filter is drained off and the clogged sand removed. When the sand bed is reduced to 18 or 20 inches a new layer is added.

The water from a slow sand filter is not only improved in color but also in the amount of bacteria contained.

It was thought at first that the filter acted only as a strainer but a bacteriological examination of the effluent shows that many bactoria too small to be removed by mere straining are removed After the filter has been in operation a few days a slimy coating is formed on the sand, and it is beleived that this coating is caused by the bacteria and is the place of their removal. This is substanciated by the fact that a filter increases in efficiency as it becomes older. The breaking or removal of this coating causes a decrease in the efficiency of the filter until a new coating has been formed. The efficiency of a slow sand filter is high especialy when preceeded by aperiod of plain or coagulated sedimentation. In many filters an efficiency of 98 to 99% is obtained with rates of from two to three million gallons per acre per day.

The rapid filters are similar the slow sand type but are of smaller area and operate under greater heads, giving higher rates of filtration. The units are small in area with a bed of sand three or four feet in depth. Because of this high rate of flow the filters must be cleaned every few hours. This is accomplished reversing the flow and agiyating the sand by mechanical means at the same time. The action of these is not exactly similar to the slow sand filter but the results are practicaly the same especialy if a coagulant is used previous to filtering. Experiments in cities having rapid filters show that are fully as efficient as the others and are more convenient in size. They require more care in operation however than the slow sand type.

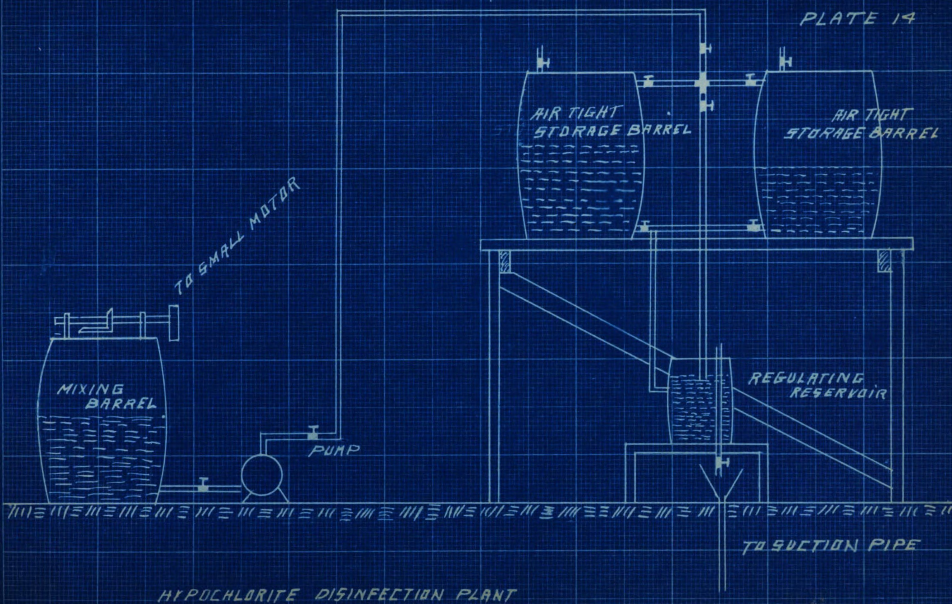
The third means of purification is aeration. This consists in placing fountains in the reservoirs or allowing the water to flow over cascades thus absorbing air. This has little effect on the organic matter present but may be of value in removing odors or preventing the growth of vegetable organisms.

Another means of removing bacteria is by disinfecting the water by the addition of some chemical. This is best done by adding Chloride of Lime to the water. This compound contains about 35% of available Chlorine which is an active germicide. Bacteria treated with this even in very dilute porportions are distroyed in a few hours. The water is not impaired by its addition in small quantities either in taste or odor. In fact the only difference which can be detected is a slight increase in hardness. A plant of this kind is in operation in Omaha Neb. in connection with settling basins. The porportion of Chlorine found most effective there was 0.3 parts per million gallons or approximately 1 part of Chloride of Lime per Million gallons of water. This represents $8\frac{1}{3}$ pounds of the chemical for this quantity of water; the bacterial efficiency being 97.4%.

From the above it will be seen that there are three ways of improving the water supply; namely mechanical filtration, slow sand filtration, and disinfecting with Chloride of Lime. The other processes are treatments preliminary to one of these three. Mechanical filters are suitable for river waters containing large amounts of suspended matter which must be removed by coagulation or sedimentation before filtering. Under these conditions they operate more successfuly than the slow sand filters which are more suitable for relatively clear lake waters.

In the case of South Haven it is beleived that the most satisfactory solution of the problem will be the installation of a slow sand filter and until this can be done it is recommended that a plant for the disinfecting of the water by Chloride of Lime be provided.

PLATE 14




HYPOCHLORITE DISINFECTION PLANT
FOR SMALL WATER SYSTEM

There seems to be some tendency towards holding Municipalities responsible for the deaths caused by a polluted water supply. The Minnesota Supreme Court has held that they are so responsible and that the deceased's heirs may recover damages. The Court of New York has however decided to the contrary. It is beleived that it will however become a question for omportant legislation before many years and it will become necessary for cities to purify their water supplies.

There are other things that might cause the spread of Typhoid besides the water supply. Open privies whose contents may filter into shallow wells or from which flies may carry infection are a constant menace to the public The people are earnestly advised to connect to the sewers where ever possible and do away with these nuisances. Much could be done to reduce the danger from flies by removing all decaying vegetablematter and refuse from stables which form a breeding place for these pests. Where there is a case of Typhoid all the excreta and waste which may have any chance of being contaminated by the patient should be thoroughly disinfected before entering the sewer or otherwise disposed of. This would do much toward reducing the danger from the water supply.

Another important item is in the ice. Nearly all the ice used localy is obtained from the river and much of it from points below the mouths of the sewers. The writer has seen ice cut oppesite the sewer at the end of Center street and no regard paid to the fact that a large part of the sewage of the city enters the river at or just above this point. This ice should not be used at all nor should any ice from the river be used where there is a possibility of its coming in contact with food or drink or with utensiles containing them. It is beleived to be within the power of the local health officer to see that no ice is cut or offered for sale from any point below the mouth of a sewer and that he would be fully justified in doing so.

DESIGN OF FILTRATION PLANT.

In working out the design of a slow sand filter the first consideration is the amount of water required per day. The maximum amount of water pumped per day is 500,000 gallons per day. The maximum rate of flow however is much larger than this and it si customary to allow 175% of the average flow as the maximum rate. The average rate of consumption is 85 gallons per capita perday. Taking 175% of this the maximum rate would be 150.5 gallons per capita.. Assuming the population, from the curve, as 5,500 in 1030 or twenty years id advance, the total maximum quantity of water required is 150.5 x 5,500 = 827,750 gallons per day. Experience indicates thatan average rate of 3 million gallons per acre per day is asafe rate of filtration. Mr. Hazen in the Albany plant assumed this rate as has been done in several other large plants. This will be the rate adopted in this design. The maximum rate required is 827,750 gallons per day or to be on the safe side I will be assumed as 1,000,000. Hence the total area required is one third of an acre.

According to modern developments it is sufficient for small beds to seperate them into three parts. In this case there would be three beds of one ninth of an acre area each so that one bed may be cleaned while the other two are in operation.

Turneaure and Russel in their discussion of slow sand filtration beds, says: "The cost of a filter may roughly be estimated as made up of two items;

(1) A portion proportional to the area which would include cost of bottom, filling, small drains, covers, and the end walls, ( basins assumed rectangular and placed side by side.)

(2) A portion nearly independent of the size, such as cost of piping, valves, valve-chamber, division walls, etc."

For this design, which is only meant as a preliminary survey of the situation, the cost cannot be estimated to any degree of accuracy. The only method of getting at it, is to compare with plants now in operation. However local conditions vary and must be considered. At ashland Wisconsin their covered filters of one sixth acre each cost 40,178 dollars. This figure was considered higher than need have been. The average cost runs at about this figure. To this cost will have to be added the cost of clear water reservoir, which amounts to about 1000 dollars.

GENERAL CONSTRUCTION.

For a small plant it is best to arrange the beds in a single row. Since they are to be covered the walls must be of masonry and water tight. Concrete well reinforced is a very satisfactory material for this purpose. The covering for them may be of the same material and preferably a straight, flat roof, which is much cheaper than the arched type and answers the purpose as well especialy for small beds. The underdrains will run crossways of each bed and connect to a single main pipe running the entire length of the three beds. This arrangement will permit the cutting off of any one bed for cleaning. This main pipe is to connect to the clear well which is located between the pumping station and the beds as shown in the plan. The clear well should have a capacity equal to the amount of water used during three hours of fire plu sthe usual demand This will give for six fire streams each delivering 200 gallons per minute and 17½ of 80 gallons a total of about 320,000 gallons. However the stand pipe may be used to supply the demand immediately after the fire and hence serve as part of the clear well. The capacity of the stand pipe is 135,000 gallons. The required size if the clear well is then about 185,000 gallons or to be entirely safe 200,000 gallons will be used.

THE FILTERING SAND.

The sand to be used must be of ordinary fineness from 0.2 to 0.4 mm. in diameter. Finer than this will cause clogging and necessitate frequent cleaning. The sand should be free from clay and any organic matter. In making up the filter bed the first layer of broken stone should be about six inches in depth and above this a lamer of finer stone until it grades into the sand at a thickness of from two to three feet. The sand layer should be from two to three feet in depth making a total depth of five or six feet. FOr cleaning the sand the modern method is to use what are called Sand scraping and washing machines.

LOCATION.

Frim the situation of the pumps with reference to the shore it would hardly be advisable to locate the beds between them and the shore as the space is small and the travel up and down the beach would be directly over them. There might also be some danger of their being disturbed in the case of unusual storms.

In this discussion only a general outline of the filter is given and no attempt is made the details of the construction.

Total area to be one third of an acre,

Three beds each one ninth of an acre in area.

Area of each bed $= \frac{1}{9} \times 43,560 = 4840$ square feet.

With this area the most convenient size of each bed is 100 x 49 feet. This excess of area will in part compensate for the space occupied by the supporting piers. The height above the sand should be at least six feet to allow for occasional high heads and give room for scraping and washing the sand bed. The head of water under which to operate can only be determined after the plant is in operation but with heads of from four to five footgood results have been obtained in similar plants. In the drawing sketched are shown the dimensions and relative positions of the beds,drains and clear wells.

PUMPING.

There is little that can be said in regard to improvements in the pumping plant. THE plant is well arranged and in an efficient state of operation. One suggestion might be made as to the division of the boiler room expense between the pumping and lighting plants.If a careful test could be made of the efficiency of the pumps when supplied by aboiler running under its full capacity a better division could be made The cost of pumping the duty of the pumps would be more nearly accurate. This would be more satisfactory to both depart ments.

PIPE LINE SYSTEM.

The pipe line is of ample size for the present demands and the only suggestion is in regard to the flushing of the pipes. The analyses of the water show that a consider ble settling action

takes place in the pipes. This sodiment may contain a considerable quantity of bacteria and although they do not multiply in this deposit they should be removeda as much as possible. When these are stirr'd up as in the case of afire they may be drawn from the taps in more than normal quantities. Flushing should be carried on in a regular and systematic manner as has been outlined before. It would be adviseable to notify the people when this was to be done and to boil all the water used during that time and for a few days afterwards. If the flushing can not be carried out in the manner outlined it would be better to flush by opening the hydrants at different points than to do nothing. Itis beleived to be as dangerous to leave the sediment in the pipes as to run the risk of not getting it all out.

MEASUREMENT.

The greater percent of the services are metered and this is one of the best means of checking wastes of water. Ameter of the Venturi type to mesure the quantity of water pumped and to check it with that delivered to the consumers would be of value. In the majotity of plants only from 50 to 70% pf the water actualy pumped is delivered to the consumers. The loss in a mile of good calked pipe may be as high as 5,000 gallons and with poorly constructed joints many times this amount. In large cities the metering of the large mains is of value in localizing the leakks but this would not be practiwable in a city the size of South Haven.

RATES.

The schedule of rates seems to be rather more complicated than is necessary in a city of thai size. There is also an objection to the low rates for the lager quantities. By refering to the

the data on the cost of pumping it is seen that the actual cost per 1,000 gallons is \$ 0.1147. Assuming that 70% of the water pumped reaches the consumers the real cost of the water delivered is \$ 0.1147 ÷ 0.70 = \$ 0.1634 . According to this the lowest possible rate at which the city can afford to sell the water is \$0.1634. A minimum rate should be fixed so as not to dis courage the use of water beyond a certain point for sanitary reasons. Water charges may be devided into two parts; one ,those expenses of operation reading meters and other similar work which does not depend upon the quantity of water pumped; second those expenses such as fuel ect. which are dependent on the quantity pumped. A common way of deviding this is to say that some porportion,as one third,of the expense is against the service and to devide this amount, plus a margin for safety,say 10%, among the services of the city in porportion to the size of the service. Some cities charge as low as \$ 1 per service but this is clearly to low to meet the expense of maintainance and reading the meters. A better charge would be,say \$ 2.00 for a 5/8" service. Ifsome users insist on a larger service in order to draw water faster let them have it but make it a basis for an extra charge. If it is an advantage let them pay for it. Starting with \$ 2.00 for a 5/8" service and using round figures for the larger sizes the scale in porportion to the rate flow would be as follows;

| | | | |
|---|---|---|---|
| For | 3/4" | meter | \$ 3.00 |
| " | 1" | " | 6.00 |
| " | 1½" | " | 13.00 |
| " | 2" | " | 22.00 |
| " | 3" | " | 48.00 |
| " | 4" | " | 85.00 |

This scale has the advantage that it makes a substantial charge for a substantial service which is often not paid for.

The remainder of the expense, that is the 2/3 plus 10% may be devided at a flat rate among the consumers in porportion to the quantity delivered. The use of a sliding scale is firmly fixed but the above contains all that is necessary of this idea or is wise. In reality it operates as a sliding scale itself.
Suppose a small user has a 3/4" service at a charge of $ 3.00 for the service and uses water at $ 0.10 per 1,000 gallons amounting to $ 3.00 The total is then $ 0.20 per 1,000 gallons. Next suppose another user has an 1½" service with a charge of $ 12.00 for the service and uses water at the same rate, $0.10 per 1,000 gallons, to the amount of $120.00. The total cost is then $132.00 for 120,000 gallons or $0.11 per 1,000 gallons.

The services to the city should be metered and paid for the same as private individuals. The fire protection is and should charged to the city and thus on the property protected. The charge of $25.00 is a very fair charge for item.

FINANCIAL MANAGEMENT.

In Municipal work it is necessary to meet the cost of construction by bond issues. Provision should be made for the payment of these by the time it may be naturally supposed the plant will have to be renewed. This is only fair as the presony generation should not be required to pay only their share for improvements the benefits of which may be partly enjoyed by future generations. The most important consideration is the manner of payment of these bonds and the length of time they should run. The plant should afford such revenues that all the operating and maintainance expenses will be met and a surplus sufficient to meet the bonds at their maturity which should be the end of the useful life of the plant. The difficulty is to estimate the average life of a complex system composed of parts of varying durability. For water works plants this may be assumed as thirty years. Some parts as the pumps may last only ten or fifteen years while the pipe line may be in good condition after thirty years of service.

There are two methods of providing for the bonded indebtedness; one the setting aside of a certain sum from the earnings each year such that when invested as a sinking fund will amount to bond issue. Besides this amount interest on the bonds must be paid each year from the earnings of the plant; second to set aside a fixed perportion of the original cost in porportion to the length of life of that portion of the plant considered. Thus if a building has aprobable life of 20 years the depreciation set aside would be 5% of the first cost. In this method the total cost will have been set aside at the end of the twenty years. This method is the more common and is on the safe side. If however thus fund is not allowed to accumulate and is turned into the general funds of the city, as is often done, there will be nothing on hand to meet the bonds. In this way a double burden is laid on the future which is manifestly unjust. For private companies earning a fair profit it is better to invest the estimated depreciation in the business than to establish a sinking fund but for municipal works the reverse is true. Municipal plants are supposed to meet only expenses and are not operated with the idea of paying dividends. For a comparison of the two methods suppose a plant costs $ 20,000 and may be expected to last twenty years. Depreciation would be estimated at 5% of the cost or $ 1,000.00 per year. If this amount were allowed to accumulate at the end of twenty years the bonds could be met by the $ 20,000.00 on hand. If a sinking fund were established at say 3½% interest on the amount necessary to be set aside annualy would be $ 707.20 on the total amount paid into the fund would be $ 14,144.00.

This method is beleived to be the better plan for Municipal plants and if faithfully followed will place them on a sound finangial basis. The great difficulty in city finance is to follow the same principles as in private enterprises, and the carelessness and lack of fore sight in carrying on the business.

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Pocket
has: 1 Map

MATERIAL